MODEL-PROTOTYPE CORRELATION OF COFFERDAM CLOSURE WITH TETRAHEDRONS

by

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ACKNOWLEDGMENT

This thesis is prepared from the results of a model study on and operated in conjuction with the closure of the second-step cofferdam at McNary Dam. The model was operated under the general direction of R. H. Berryhill, Head, Hydraulic Design Section and J. E. Reeves, Chief, Engineering Division of the Walla Walla District, Corps of Engineers. The Bonneville Hydraulic Laboratory was directly responsible for the model study under the direction of R. B. Cochrane, Head, Hydraulic Design Section and M. J. Webster, Head, Bonneville Hydraulic Laboratory, Portland District, Corps of Engineers. Actual model operation was carried out under the direction of the author assisted by Hugh A. Smith, Jr.; Ray Skrinde; Daniel J. Gee; Marion Bescup; Kieth Hadley; Edwin Jones; Gail Gronewald; Jim Cannon and Loren McDonald. Liaison was carried on between the construction forces and the model study through S. Neff, Resident Engineer and Major D. Donald, Engineer, McNary Dam.

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MODEL-PROTOTYPE CORRELATION OF COFFERDAM CLOSURE WITH TETRAHEDRONS

Closure of the second-step cofferdam, McNary Dam was begun on October 10, 1950. This closure was unique in that it was made with 12-ton concrete blocks of tetrahedral shape; the first time on record that a closure of this magnitude had been made by this method. Model tests were made prior to and during the actual cofferdam closure, and the results were incorporated into the prototype construction schedule. This thesis presents the results of studies made on a 1:24-scale model of the closure section with particular emphasis on the model-prototype comparison of fill construction. The model was constructed at McNary Dam during October 1950, and testing was completed November 18, 1950. Operation of the model was carried out under the direction of the Walla Walla District, Corps of Engineers with personnel of the Bonneville Hydraulic Laboratory in direct charge of model construction and operation.

McNary Dam, located on the Columbia River approximately 3 miles upstream from Umatilla, Oregon, is principally a power and navigation improvement dam. The powerhouse, spillway, and navigation lock are located in line as shown on Plate 1. The second-step cofferdam encompasses the powerhouse and remaining portion of the spillway not completed during first-step construction (Photograph 1). During the time the second-step cofferdam is in place, the river discharge is bypassed through 12 low bays (Elev 250) of the spillway (Photograph 2).

The schedule on which McNary Dam is being constructed can be described briefly as follows:

a. First-step construction including the navigation lock, Washington shore fishladder, and 13 bays of the spillway was completed during the spring of 1950. This construction was done within the first-step cofferdam which was located along the Washington shore.

b. The second step included construction of Bays 14 to 22 of the spillway and the complete powerhouse substructure. The upstream leg of the second-step cofferdam was to be completed by January 1, 1951, and the downstream leg by May 1, 1951. It was necessary that closure of the upstream leg of the second-step cofferdam be completed on the above date due to the flow characteristics of the Columbia River. If for any reason the cofferdam would not have been completed at this time, the summer high water would postpone construction in this area until late summer of 1951, thus delaying the entire project for approximately 1 year.

c. Contracts for completion of the dam are scheduled in consecutive order so that power from Units 1 and 2 of the powerhouse will be forthcoming by December 1, 1953.

The second-step cofferdam of which the closure of the upstream leg is the subject of this thesis is shown on Plate 1. It will be noted that the topography divided the river into two distinct channels at the dam site. The channel along the Oregon shore was the original navigation channel. Construction plans called for completion of the upstream leg of the cofferdam, except for the 240-ft closure section in the Oregon channel, by November 1, 1950. With the upstream leg of the cofferdam completed, work could progress on the downstream leg in quiet water. The cofferdam would be overtopped during the summer high water periods as it was not designed to protect against flows in excess of 362 000 cfs.

Construction of the closure section was planned as shown on Plate 2. Model tests in a glass-walled flume at the Bonneville Hydraulic Laboratory had indicated that velocities up to 27 fps would occur over the downstream slope of the fill at some stages of construction. Results of investigations made previously, particularly those of S. V. Isbash[1], indicated that to resist overturning at 27 fps, a round stone of 10 000 lbs. would be required. Stones of 16 000 lbs. would not overturn in velocities of 29 fps. Tetrahedral shapes (Photograph 4) were selected because of their physical characteristics of greater resistance to overturning than rounded stones or concrete prisms. Referring to Section A-A, Original Design, Plate 2, Zone 1 was designed as the tetrahedron portion of the fill. The secondary layer, Zone 2, was to consist of "B" stone designated as being rock one ton or heavier. Next, another layer of tets was to be placed along the downstream toe of the fill followed by another layer of "B" stone. This procedure was to be followed until the fill was completed, at which time the impermeable layers of silt were to be placed on the upstream face of the fill. On Plate 2 is also shown a typical section of the fill as it was finally constructed. It will be noted that in general, this section is similar to the original design although the outline of the various stages of construction varied from the design section.

The model (Plate 3 and Photographs 3 and 5) was constructed at McNary Dam. The major purpose for the model study was to provide information and visual observation of the fill characteristics at various stages of construction. Due to the fact that little information on closure of a cofferdam using this method was available, the model was used to illustrate the various problems involved and to give the construction engineers a better insight on how the fill was progressing during the various stages of construction. In all, six separate tests were made in the model. The first five of these tests were run to observe fill construction for varying discharges and methods of construction, whereas, the sixth test duplicated the prototype fill construction to determine model-prototype conformity.

Model bottom topography (Plate 3 and Photograph 6) was built to prototype soundings made by the Corps of Engineers in 1935, except for topography on the alignment of the upstream leg of the cofferdam which was built to soundings taken in 1948. During operation of the model, it was noted that model soundings did not agree with additional prototype soundings taken during October 1950. Tests 1 to 5 were made with topography as surveyed in 1935 and 1948. Just prior to Test 6, the model bottom topography was revised to include soundings taken in the river during October 1950. Plate 4 shows a comparison of model topography as installed for the various tests. It was observed that the river bank in the vicinity of the cofferdam was very rough, and it was assumed that the bottom topography would be of similar nature. Therefore, the model was roughened with stones 2 to 3 inches in diameter spaced approximately 6 inches on center which simulated a prototype roughness factor of approximately 0.038 in "Mannings" open channel formula. A comparison of model and prototype bottom characteristics can be made from Photographs 6, 50, and 51. Model flow conditions prior to the placement of tets are shown in Photograph 7.

Test 1: At the time the model was completed and ready for operation, a total of 439 tetrahedrons plus 2260 tons of "B" stone had been dropped in the prototype closure section. Tetrahedrons (to scale) were dropped, and "B" stone was placed in the model under the same hydraulic conditions in effect during the dropping schedule in the river. Photographs 8 and 9 show the similarity of flow in model and prototype at this stage of construction. At the end of this run, the model was unwatered, and the fill was sounded and contoured as shown on Plate 6. It was found that a good comparison existed between model and prototype fill contours. Progressing from that point, tets were dropped along a line 50 ft. downstream from the cofferdam centerline on a schedule laid out by the construction engineers. During this second phase of Test 1, the model was controlled by the pool and tailwater elevations as indicated in the 1:100-scale McNary

General Model at the Bonneville Hydraulic Laboratory. Operation of the general model with the second-step cofferdam in place and the fill at various elevations had determined pool and tailwater elevations that would exist at various river stages; however, these data were approximate only because of an impervious fill in the model, a trapezoidal-shaped fill in the model as contrasted to the sharp-crested prototype fill, and questionable similarity of high topography near the spillway. On October 28, 1950, the day this particular test was begun, the river discharge was 117 000 cfs, and an operating curve for this discharge was assumed. Since facilities for measuring the percentage of river discharge being bypassed through the low bays of the spillway are lacking, it was necessary to operate the model by pool and tailwater elevations by adjusting the water supply and tailgate. The flow passing through the spillway at various stages of fill construction was difficult to estimate due to the high topography both upstream and downstream from the spillway section (Photographs 2 and 31). In this test, a total of 892 tets were dropped in the model together with 2260 tons of "B" stone. The test showed that better results would accrue if the dropping line for tets 439 to 892 was moved 5 ft. upstream.

An explanation of the prototype fill construction schedule is necessary at this time to show the manner in which it was developed. With the approximate bottom or fill elevation determined from soundings, the number of tetrahedrons necessary to raise the fill to a certain elevation was computed by assuming that the upstream slope would be 1 on 1, the downstream slope 1 on 1 1/2 and that 45 per cent of the fill would be voids. These tetrahedrons were then scheduled to be dropped from certain points along a line some distance downstream from the centerline of the cofferdam. The first group of tets, 0 to 439, was dropped on a line 60 ft. downstream as indicated on Plate 10, and succeeding groups were dropped at various distances from the centerline. However, it developed in the model that following the schedule blindly would tend to leave low spots in the fill which were evidenced by "slicks" on the water surface above them. A "slick" was defined in this particular case as an area of smooth water extending into the turbulent flow downstream from the fill (Photographs 15 and 34). It was extremely important that the fill be raised uniformly because low points in the fill were extremely difficult to close. Therefore, it was decided that the schedule would act merely as a guide, and that it would be altered as low spots in the fill were indicated by "slicks" on the water surface.

The important findings of Test 1 were: (1) the second group of tets (439 to 892) should be dropped from a line 45 ft. rather than 50 ft. downstream from the centerline of the cofferdam, and (2) that the dropping schedule should be altered as "slicks" appeared on the water surface at the time the tets were being dropped to prevent the occurrence of low spots in the fill.

Test 2: The second test consisted of constructing a fill by dropping tets in the model with a simulated river discharge of 117 000 cfs; dropping points were selected entirely on the basis of fill appearance and relative retainment of tets on the crest of the fill. Low spots in the fill were closed as they appeared; as the percentage of tets carried downstream to the toe of the fill increased, the dropping points were moved upstream to a region of lower velocities. This test showed that the closure could be made to approximate Elev 260 with a total of 1846 tets. Conditions in this case were ideal in that the fill could be observed at all times and the dropping points for the tets altered as conditions warranted so that relatively few of the tetrahedrons were lost to the downstream toe of the fill, thus not contributing to the height of the fill. This method would not be practical in the prototype as the action of the tets, as they were released, could not be observed.

Test 3: By the time the second test in the model had been completed, a total of 987 tets plus 2260 tons of "B" stone had been dropped in the river and the discharge of the Columbia River had risen to approximately 150 000 cfs. With the first 987 tets dropped in the model with conditions similar to those existing in the prototype (Photograph 14), a fill was constructed in the model with an operating curve based on the assumption that the river discharge would crest at 150 000 cfs and then fall slowly to 140 000 cfs as the fill was increased in height. Again the pool and tailwater elevations were based on data obtained in the 1:100-scale McNary General Model. It was evident that these operating conditions could be only calculated guesses. As the test progressed, it became evident that flow conditions in the McNary General Model were more severe than conditions encountered in the prototype. Tets and "B" stone were dropped in successive stages, keeping the downstream edge of the fill some 10 ft. above the top of the "B" stone. The fill was completed for all practical purposes to Elev 268 with a total of 2275 tets. This test showed that the fill could be made with the higher discharge, but that the difficulty of placement was increased. At the time the fill was completed, its upstream edge was located approximately 55 ft. upstream from the centerline of the cells.

Test 4: Test 4 was run with operating conditions similar to those used in Test 3; i.e., pool and tailwater elevations based on a river discharge of 150 000 cfs decreasing to 140 000 cfs. The fill was constructed according to a scheme in which the "B" stone was kept practically level with the top of the tet fill; the theory being that it would be possible to decrease the number of tets required to make the fill by replacing them with less expensive "B" stone. The final results of the test indicated that the total number of tets used in the construction of the fill was approximately the same as required in the previous test. Although a larger amount of "B" stone was used, a greater number of tets were swept downstream. It was noted that in dropping the first series of tets above 987, with "B" stone level with the tet fill, stability of the tets was considerably less than in the previous test. Evidently the 10-ft. lip remaining on the downstream end of the fill in Test 3 was sufficient to act as a key against which succeeding tetrahedrons could lodge and be retained on the fill. It was noted that a large percentage of tets, in the group numbers 988 to 1329 (fill Elev 248 to 250), were swept downstream by the high velocity flow which occurred during this particular stage of construction.

Test 5: Test 5 consisted of rerunning Test 3 under identical operating conditions and dropping schedule disregarding the appearance of the fill itself. This test was run for the purpose of determining whether the model would reproduce itself. The results showed that at the end of the test the average fill height was approximately 1 ft. lower than in Test 3; however, the appearance of the fill compared favorably with the original. One or two low spots were developed in the fill, but not serious enough to differ radically from that observed in Test 3. The results of Test 5 demonstrated that the model would reproduce itself when operated under identical conditions.

Test 6: Test 6 was run for the express purpose of making a model-prototype comparison. Whereas, the previous tests had fulfilled the major purpose of the model study, namely that of serving as a guide for the construction engineers in planning the construction of the prototype fill, Test 6 served as a check on model-prototype correlation and the relative accuracy of the model as far as the prototype was concerned. Prior to the beginning of this test the model bottom topography was rebuilt to the latest prototype soundings obtained in October 1950, and discussed previously. From that point the model was operated under conditions identical to the prototype as listed on Plates 10 and 10A. The dropping location, pool elevations, and tailwater elevations were followed meticulously throughout the test. As prototype observations were not complete for all construction phases, considerable reliance was placed on photographic comparison.

Prototype soundings usually were made on Sundays during construction of the fill; therefore, duplicate model data had to be referred to fill conditions existing on those particular days. Reference to Plate 10 will show that 439 tets were placed in the original drop schedule. A good set of soundings and velocities were obtained for this fill condition during the succeeding weeks when it was not possible to work on the fill section. Model-prototype comparison of fill conditions at the end of 439 tets is illustrated on Plate 6 and Photographs 8 and 9. At this stage of fill construction, the model reproduced prototype fill conditions and velocities with remarkable accuracy. It was found that this first group of tets piled up in the shape of an isosceles triangle with upstream and downstream slopes approximately 1 on 1 1/4 (Photographs 10 and 11). From this point, "B" stone was dropped in the model with a skip (Photograph 12) with the quantity controlled by weight as determined from Froudian model to prototype relationships. Photograph 13 illustrates an interim condition at which time prototype sounding data were not available. By the following Sunday (November 5, 1950) 987 tets and 8000 tons of "B" stone had been dropped in the river. For all practical purposes the effect of the "B" stone could be disregarded since any effect it had on the discharge was not reflected by any of the gages shown on Plates 10 and 10A.

At this stage of the fill construction, the model fill appeared to increase in height much more rapidly than did the prototype fill. Plates 5 and 7 illustrate this condition and show that the model fill was some 15 ft. higher at the center than shown by available prototype soundings (Photographs 14 to 17). In regard to prototype soundings, it should be noted that these data at this stage of fill construction were very meager due to a lack of adequate sounding equipment for the high velocities and turbulent flow conditions encountered. Photograph 49 illustrates some of the sounding weights used. It was found that a triangular shaped weight made of lead-filled pipe was the most satisfactory of those tried. Velocities, measured with a current meter, agreed satisfactorily with those measured in the model (Plate 7).

The reasons for the variation between the model and prototype fills at this stage of construction (987 tets) are somewhat obscure but are probably contained in a combination of the following factors:

a. The difficulty encountered in obtaining prototype soundings of the fill as discussed previously.

b. The actual prototype dropping schedule may have varied from that used in the model as to skip location with respect to control grid (Plate 7), height of skip above water surface, and number and sequence of tets dropped at each location. In this set of prototype observations, some uncertainty existed in the latter two items. While it was possible in the model to accurately control these conditions, the recording of the actual prototype dropping schedule involved considerable estimation.

c. The flow velocities in the model and prototype agreed satisfactorily, and the water-surface elevations were set in the model from prototype gage readings. However, the actual amount of discharge which resulted in the velocities and water-surface elevations used was difficult to determine. An approximate check was afforded from a tentative rating curve developed for Gage 22 after closure was complete (Plates 1 and 9). From an extrapolation of this curve and reference to Gage 22 data secured during the fill construction (Plates 10 and 10A), it was possible to approximate the percentage of river flow passing through the closure section.

d. Due to possible variation in flow between model and prototype, the drift of the tets after dropping may have varied. Floats were tied to several tets during various stages of the fill construction in an attempt to determine the number of tets drifting off the fill. Drifts of 0 to 85 ft. were recorded, but a definite pattern for comparison with the model was not established.

e. It is recognized that all physical characteristics of the prototype cannot be reduced in scale (Froudian) and their effects kept in direct relation. Model-prototype interpretation must be based on the relationships between predominating influences. It is regrettable that uncertainties crept into the prototype data at this time because this stage of the fill construction, tets 439 to 987, greatly influenced subsequent tet placement.

In spite of the variation in the model and prototype fills, it was decided to continue the prototype schedule in the model above 987 tets. "B" stone totalling 13 157 tons (prototype) was added to the model, at which time flow conditions were as illustrated by Photographs 18 and 19. Note the similarity of the stationary waves due to a high point in the "B" stone fill in model and prototype. As the fill progressed in the model, the central portion rose steeply with low areas at both ends (Photographs 20 and 21) until at 1348 tets the center of the fill had cleared the water surface with the major portion of the flow passing along both sides (Photographs 22 to 25). At this stage of model fill construction, it was obvious that little could be gained by continuation of this phase. Therefore, it was decided to proceed to the next point at which good prototype soundings were available and rebuild the model fill. Photographs 26 to 29 are shown to illustrate river flow conditions during the interim period between tets 1348 and 1664 which was not developed in the model.

The model fill was rebuilt to prototype soundings as available on November 12, 1950 (Plate 8), at which time 1664 tets and 20 309 tons of "B" stone were in position (Photographs 30 and 32 to 35). An extensive set of soundings was available and an accurate simulation of the prototype fill was made. The model fill was carried per schedule (Plate 10A) complete with "B" stone to a total number of 2088 tets at which time, for hydraulic purposes, the fill could be considered complete. Photographs 36 to 39 illustrate flow characteristics at various stages of this fill. Prototype soundings were lacking for the final stage of fill construction, but Photographs 40 to 45 indicate close similarity of model and prototype fills. From Plate 5 it can be seen that the downstream slope of the fill at 2088 tets was approximately 1 on 6 at completion. The upstream portion of the fill rose steeply once the flow had been diverted sufficiently. It appeared that the model did reproduce prototype conditions satisfactorily for this particular phase of fill construction. Tets 2089 to 2505 were dropped on top of the fill to build up the section between Cells 16 and 17 and should not be considered as far as building of the fill was concerned. It is believed that after 2088 tets had been placed other material could have been used with similar results.

With fill construction as of November 18, 1950, at which time 2505 tets and 27 585 tons of "B" stone were in place, a measurement of the seepage was made both in the prototype and in the model. With a river discharge of 117 000 cfs in the river and conditions as illustrated by Photographs 46 and 47, the seepage and cascading flow were estimated to be 10 600 cfs in the prototype and 11 300 cfs in the model. To differentiate between the cascading flow and seepage through the fill, the pool elevation was dropped in the model to Elev 250.7 approximately 16 ft. below the average top elevation of the fill; tailwater was set at Elev 240.5. With this 10-ft. differential in the model, a flow of 2800 cfs was measured as seepage through the fill. This completed the model tests as of November 18, 1950. Subsequent to this date all tets constructed, totalling some 3200, were placed in the fill (Photographs 47, 50, and 51).

Conclusion: It is believed that the model served the purpose for which it was intended, i.e., a guide whereby construction engineers were able to view the action of the fill under various conditions and plan the construction schedules accordingly. In this respect, the model proved invaluable and enabled the prototype closure to be made with relatively little difficulty, the ultimate requirement in any case. In all probability the closure would have been made in the river without the aid of the model; however, the model permitted a much more economical use of material. Engineers from all parts of the United States visited the project during the construction of the closure section and at the same time viewed the model in operation. It is believed that operation of the model gave these engineers a better picture of what was occurring in the prototype where only the water surface could be observed.

The fact that the model did not exactly reproduce the prototype fill section in all respects can be attributed to various factors as mentioned previously. That the model-prototype comparison was successful to some degree (tet numbers 0 to 439 and 1664 to 2088) can be considered a significant fact, and presumably a basis for the statement that prototype happenings can be forecast in a model of this type. It is unfortunate that more complete prototype data were not obtained.

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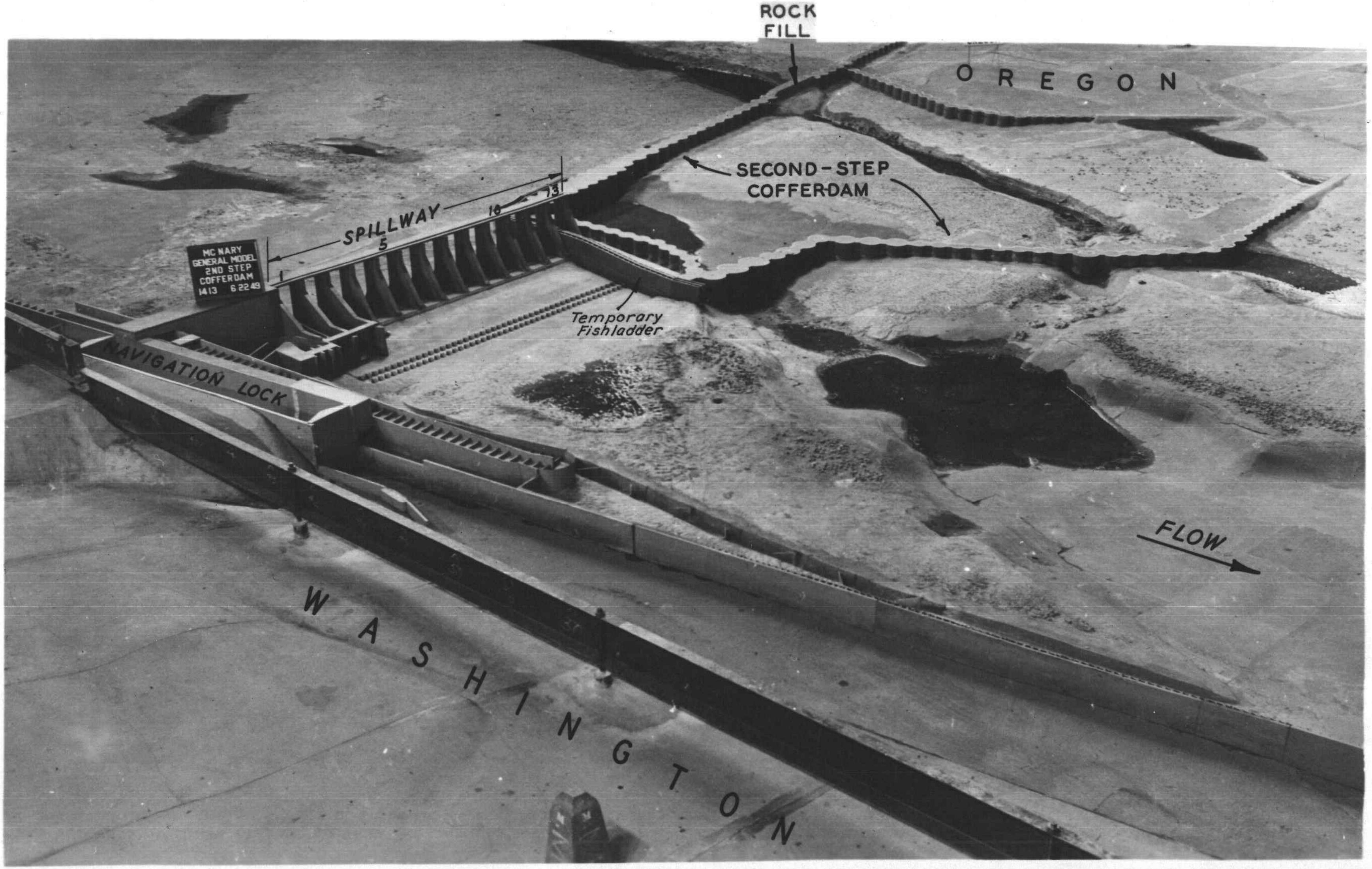
P H O T O G R A P H S



Photograph 1

First-step structures and second-step cofferdam installed in 1:100-scale general model.

Photograph 2

Photograph 3

9 November 1950

Tets 1390
"B" Stone 14 250
River Discharge . . 137 000 cfs

General view of McNary Dam, Second-Step Cofferdam Closure. Note flow through spillway in background.

Upstream view of Cofferdam Closure with 1:24-scale model in center foreground.

Photograph 4

12-ton tetrahedrons used in Second-Step Cofferdam Closure.

Photograph 5

Upstream view of 1:24-scale McNary Cofferdam Closure Model.

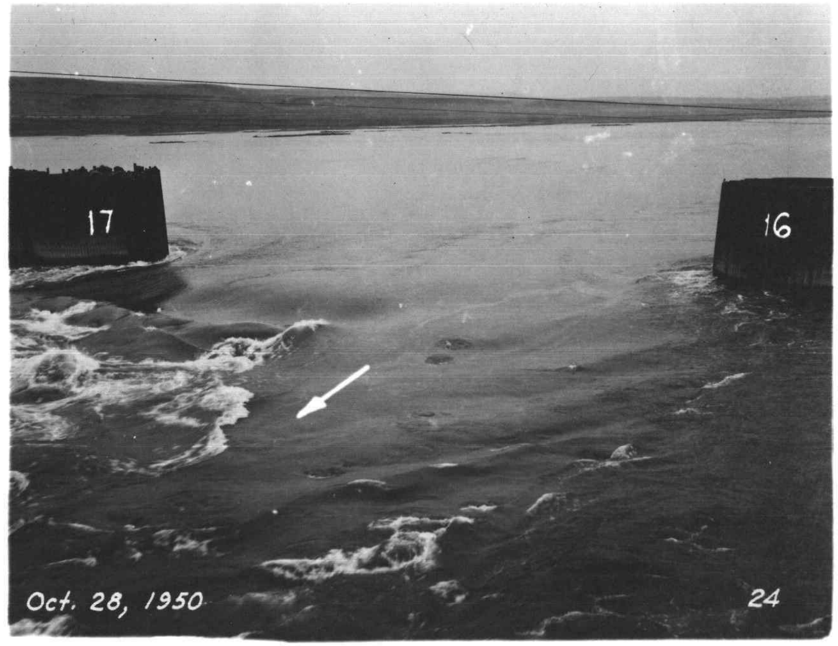
Photograph 6

Downstream view of model river bed prior to start of closure.

Photograph 7

River Discharge	96 000 cfs
Pool Elev	255.2
Tailwater Elev	253.2

Flow through closure section prior to start of fill.

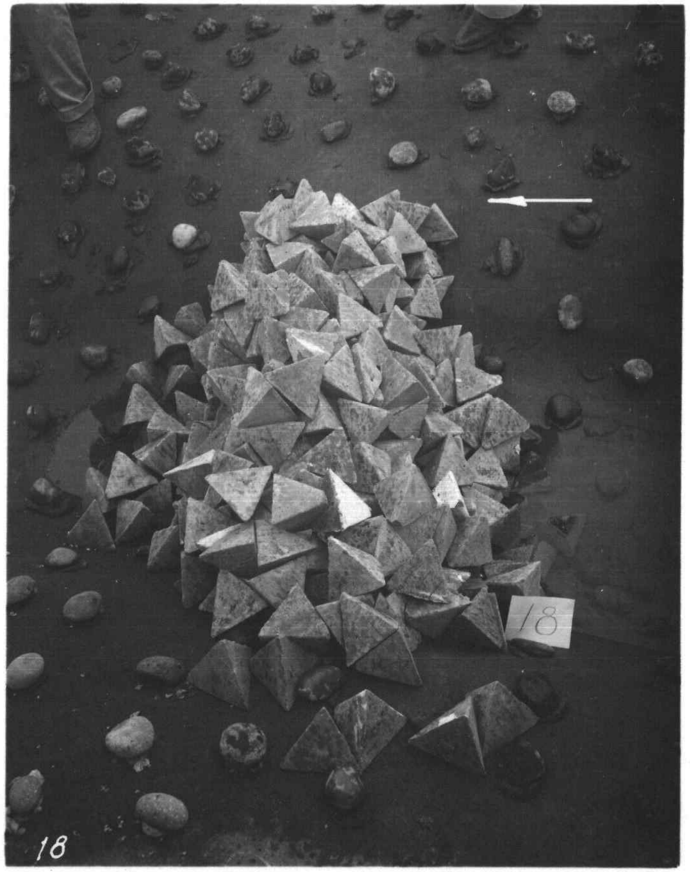


Photograph 8

Photograph 9

Fill Elev 240
28 October 1950

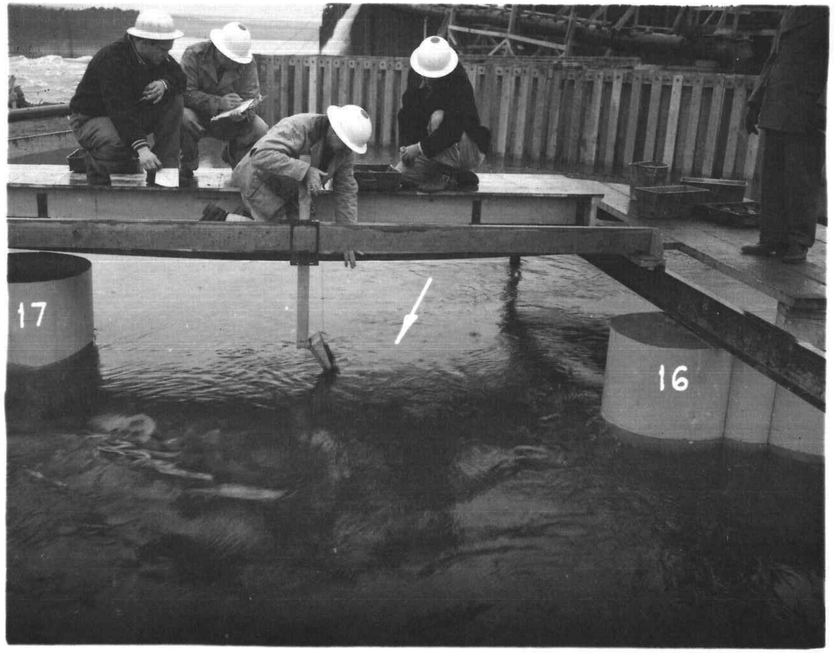
MODEL		PROTOTYPE
439	Tets	441
2260 tons	"B" Stone	2260 tons
95 000 cfs	River Discharge	117 000 cfs
258.5	Pool Elev	260.9
253.8	Tailwater Elev.	256.2



Photograph 10

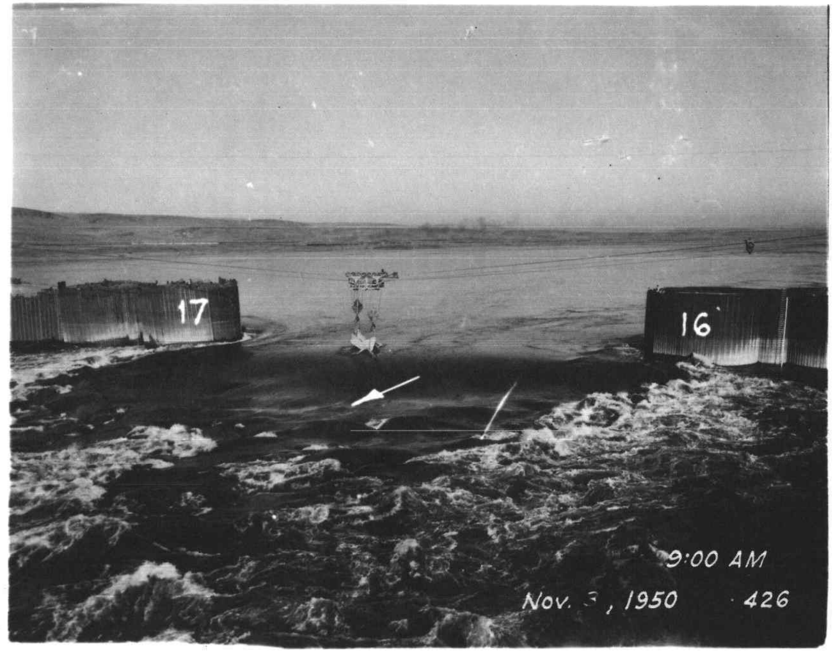
Photograph 11

Model Fill Elev 240
439 Tets



Photograph 12

Placement of "B" stone in model by skip load.



Photograph 13

Cofferdam closure section, 3 November 1950.

MODEL		PROTOTYPE
439	Tets	895 plus 2260 tons "B" stone
105 000 cfs	River Discharge	144 000 cfs
258.5	Pool Elev	263.9
254.5	Tailwater Elev.	257.4

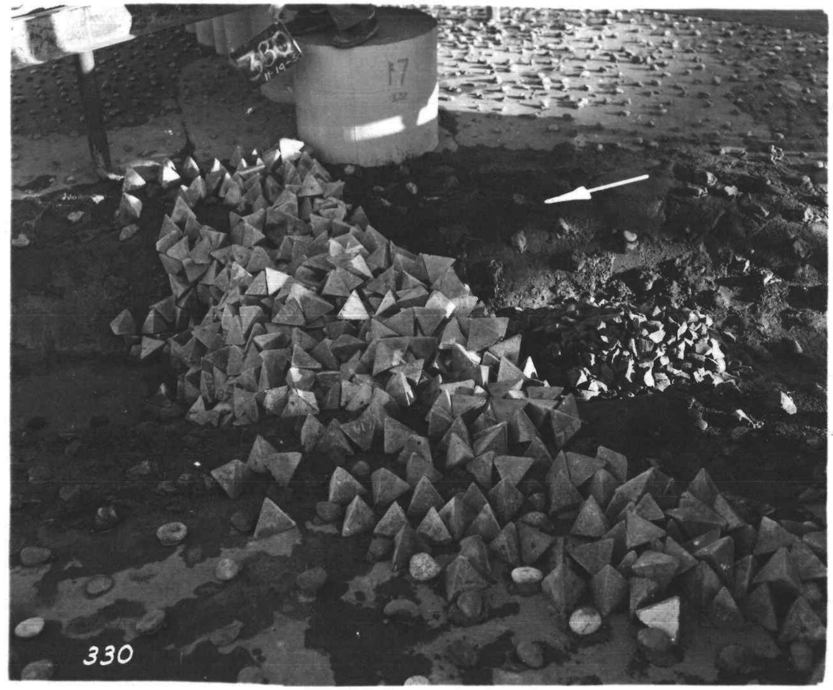
Photograph 14

Photograph 15

4 November 1950

MODEL		PROTOTYPE
987	Tets	987
2267 tons	"B" Stone	5500 tons
146 000 cfs	River Discharge	157 000 cfs
264.6	Pool Elev	265.2
257.2	Tailwater Elev	257.6
249	Average Fill Elev	240 Plus

Photograph 16



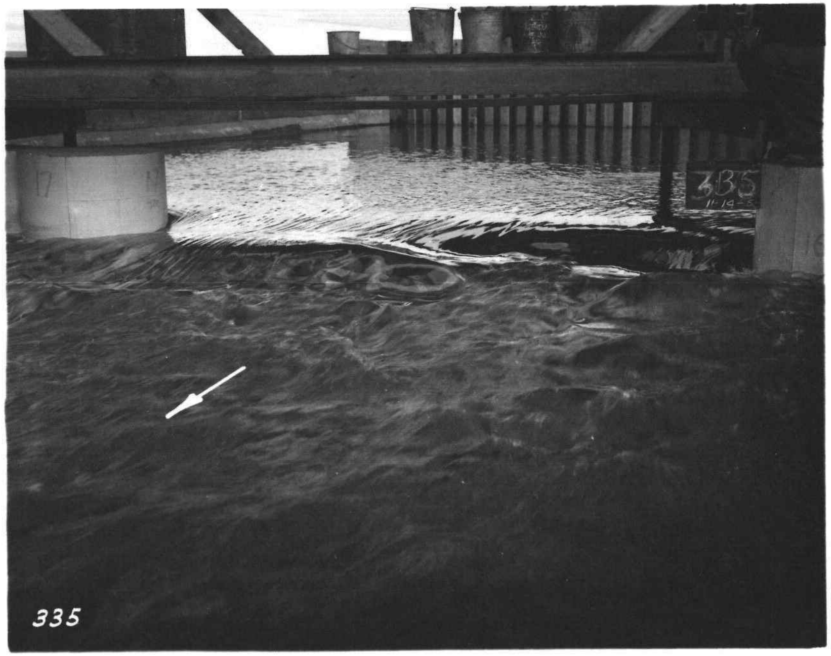
Photograph 17

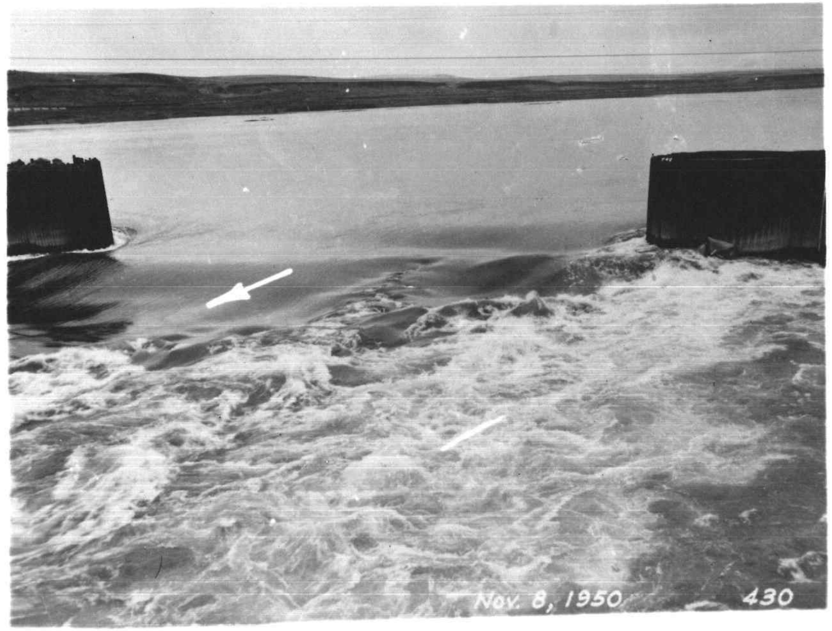
MODEL

Tets 987
"B" stone. . . . . 2267 tons
Average Fill Elev. . . 251.8

River Discharge. . . . . 146 000 cfs
Pool Elev. 264.6
Tailwater Elev 257.2

Dry Bed



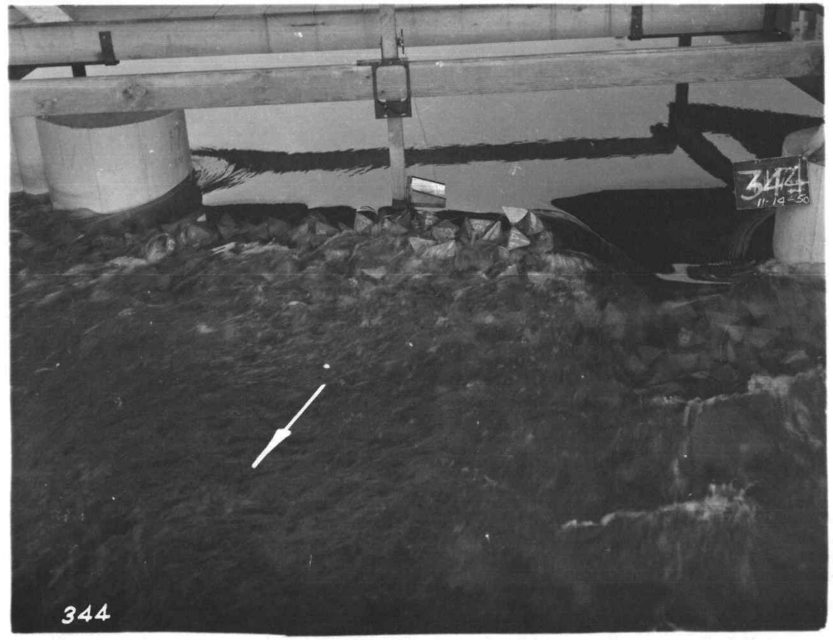


Photograph 18

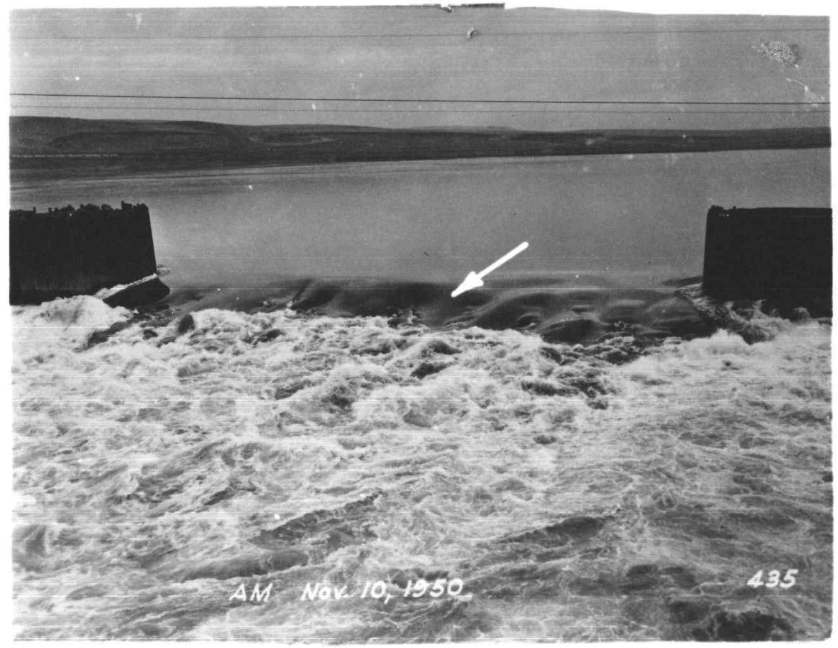
Photograph 19

8 November 1950

MODEL		PROTOTYPE
987	Tets	1079
13 157 tons	"B" Stone	13 157 tons
148 000 cfs	River Discharge	143 000 cfs
264.7	Pool Elev	264.8
257.4	Tailwater Elev.	256.7
251.8	Average Fill Elev	



Photograph 20	MODEL	Photograph 21
1138	Tets	1200
13 156 tons	"B" Stone	13 156 tons
143 000 cfs	River Discharge	143 000 cfs
264.9	Pool Elev	265.0
256.6	Tailwater Elev	256.3

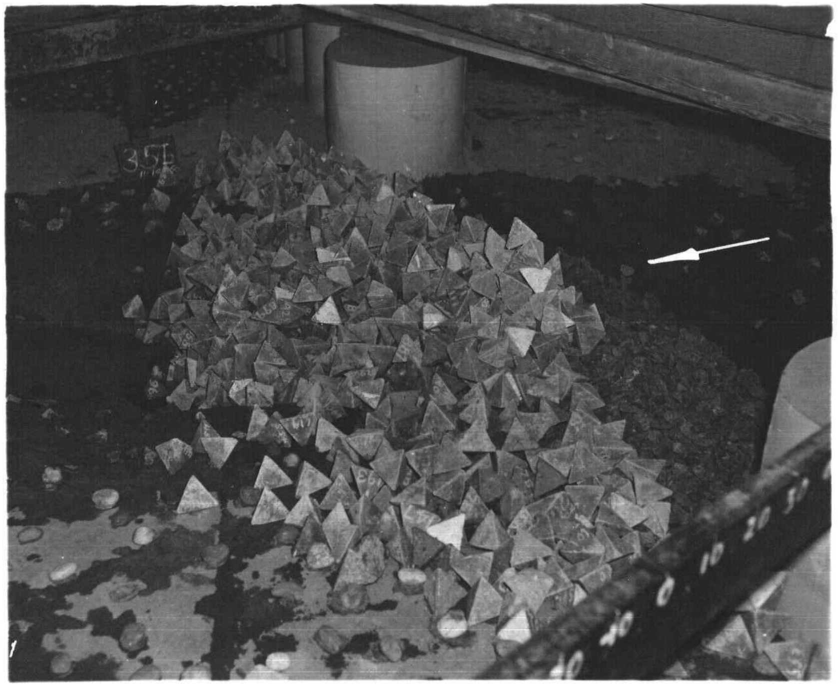


Photograph 22

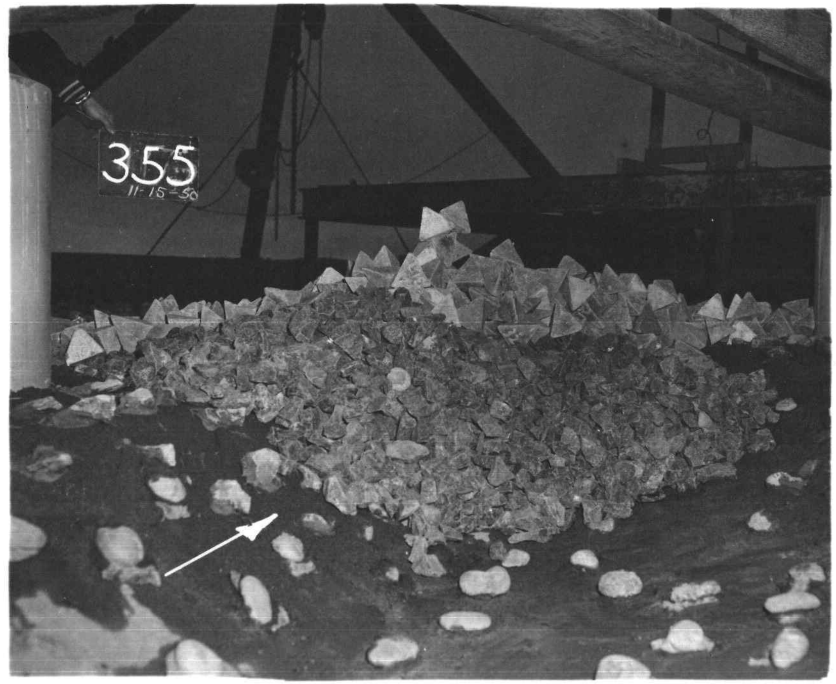
Photograph 23

10 November 1950

MODEL		PROTOTYPE
1348	Tets	1390
13 156 tons	"B" Stone	16 300 tons
139 000 cfs	River Discharge	136 000 cfs
265.4	Pool Elev	265.7
256.4	Tailwater Elev	256.3



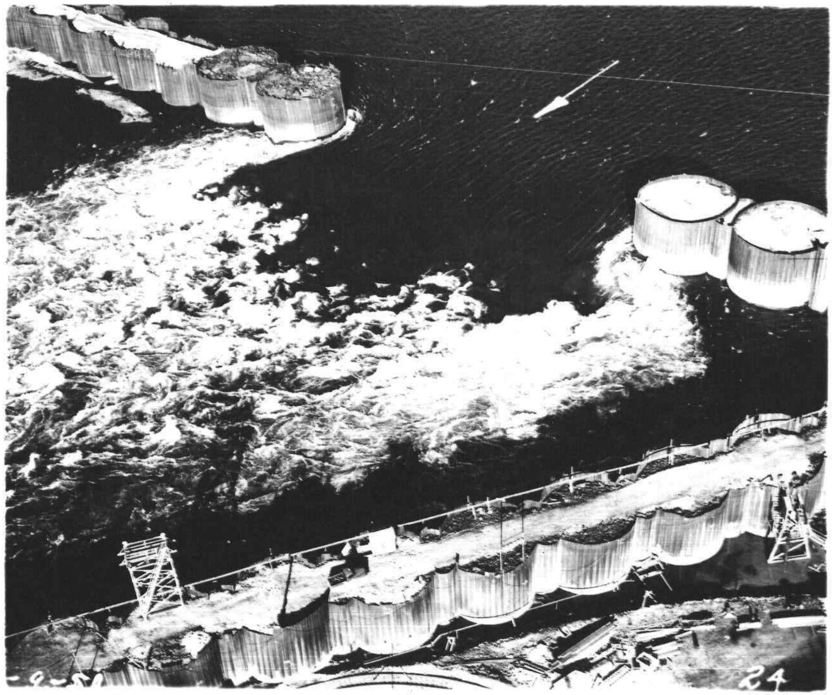
Photograph 24



Photograph 25

Model Fill

Tets 1348
"B" Stone 13 156 Tons



Photograph 26

Closure Section

Photograph 27

Construction of powerhouse Units 1 and 2 within Oregon shore cofferdam.

9 November 1950

Tets	1390
"B" Stone	14 000 Tons
River Discharge . . .	137 000 cfs
Pool Elev	265.7
Tailwater Elev.	256.4

Photograph 28

Photograph 29

9 November 1950

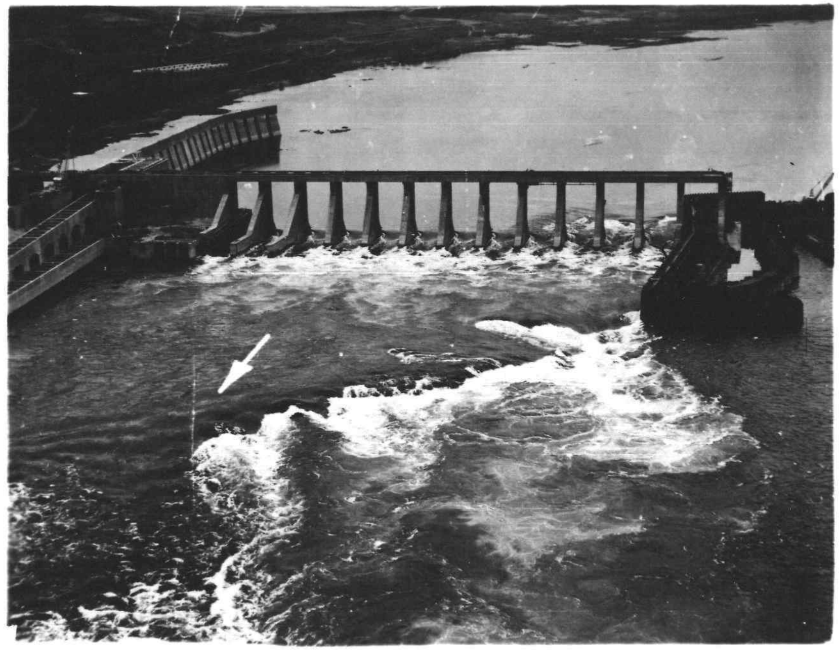
Tets	1390
"B" Stone	14 000 Tons
River Discharge . . .	137 000 cfs
Pool Elev	265.7
Tailwater Elev.	256.4

Aerial views of Cofferdam Closure Section.

Photograph 30

Tets 1664
"B" Stone . . . 20 309 tons

Model Fill



Photograph 31

By-passing flow around second-stage cofferdam through 12 low bays (Elev 250) of spillway.

Closure Fill Status

Tets 1664
"B" Stone . . . . 17 560 tons
River Discharge . . . 131 000 cfs
Pool Elev 266.8
Tailwater Elev. . . . 255.4
Average Fill Elev . . 252.5

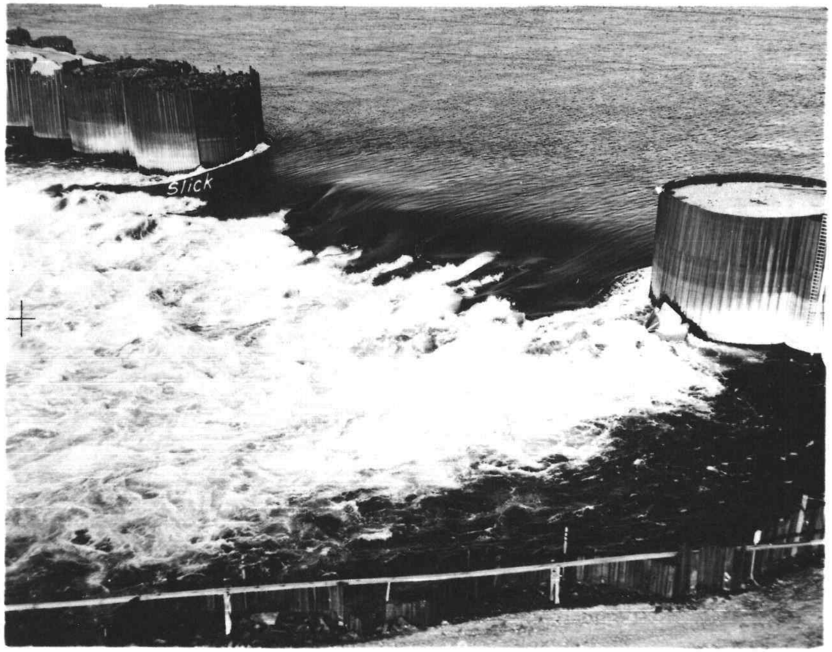
Photograph 32

Model

Photograph 33

12 November 1950
Prototype

Tets	1664
"B" Stone	20 309 tons
River Discharge	124 000 cfs
Pool Elev	266.6
Tailwater Elev.	255.1
Average Fill Elev . . .	252.5



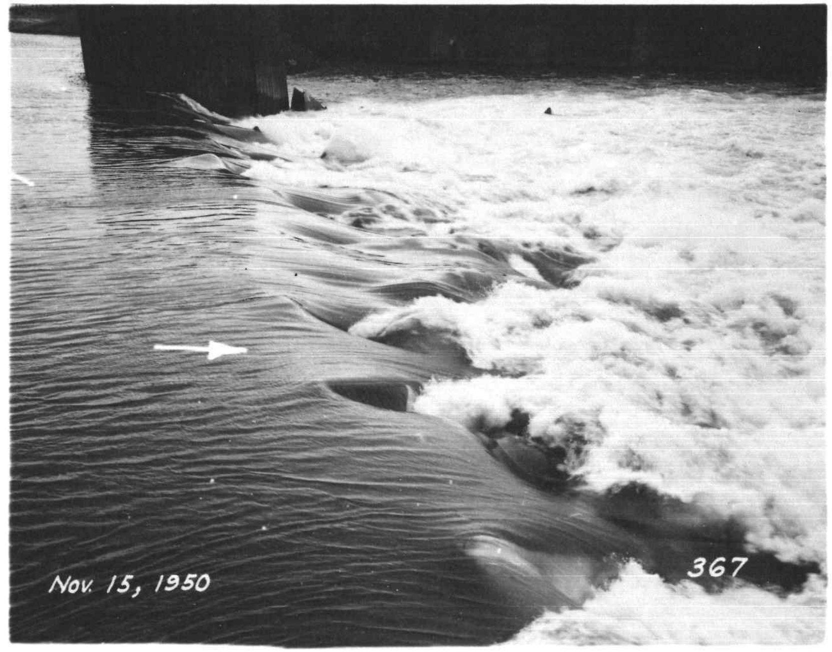
Photograph 34

Photograph 35

Prototype Closure Section
14 November 1950

Tets	1664
"B" Stone	26 000 tons
River Discharge	118 000 cfs
Pool Elev	266.4
Tailwater Elev.	254.6
Average Fill Elev . . .	252.5

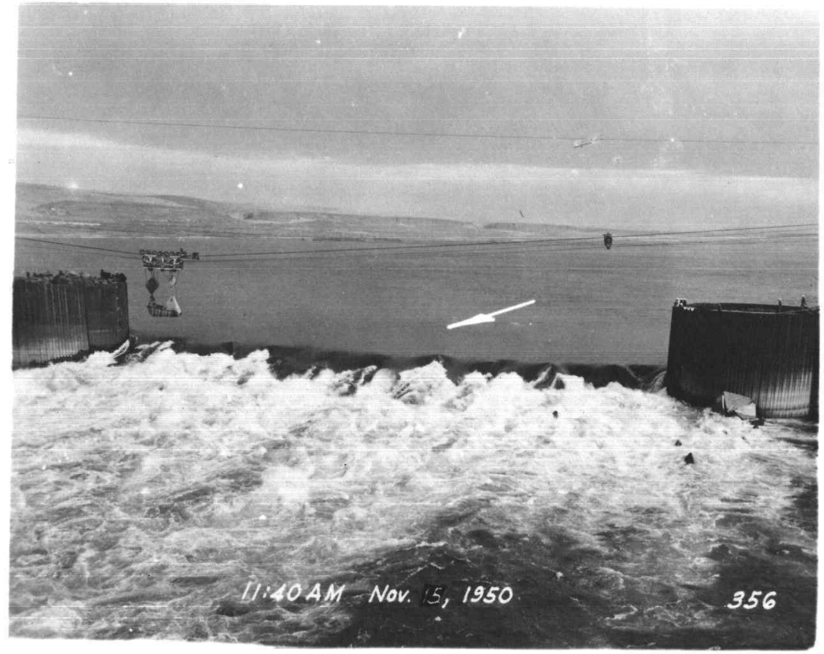
Photograph 36



Photograph 37

Prototype Closure Section
15 November 1950

Tets	1766
"B" Stone	27 585 tons
River Discharge . . .	116 000 cfs
Pool Elev	266.8
Tailwater Elev. . . .	254.3



Photograph 38

Photograph 39

15 November 1950

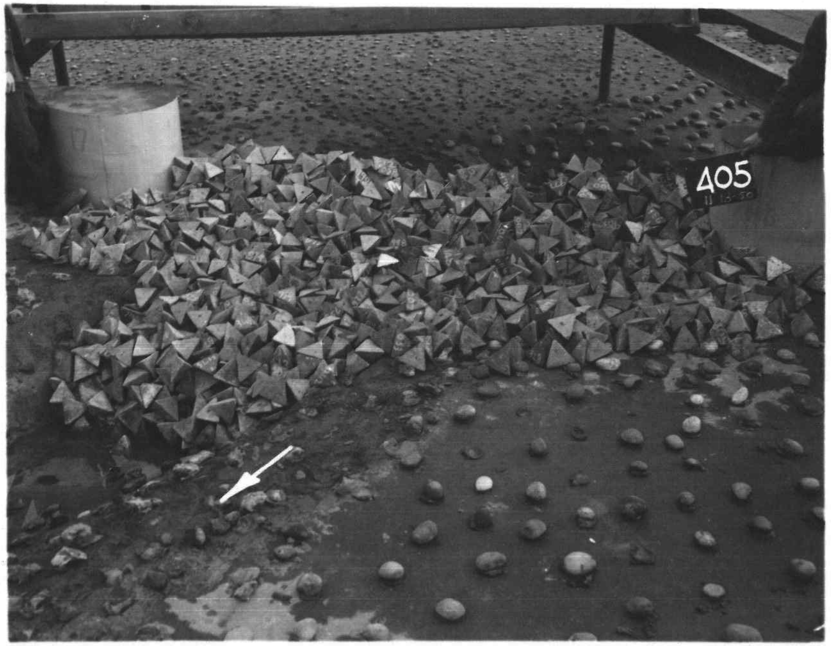
MODEL		PROTOTYPE
1824	Tets	1800
27 585 tons.	"B" Stone	27 585 tons
115 500 cfs.	River Discharge.	115 000 cfs
267.2.	Pool Elev	267.1
254.0.	Tailwater Elev.	254.0

Photograph 40

Photograph 41

16 November 1950

MODEL		PROTOTYPE
2088	Tets	2088
27 585 tons	"B" Stone	27 585 tons
113 000 cfs	River Discharge	113 000 cfs
268.0	Pool Elev	268.0
253.4	Tailwater Elev	253.4



Photograph 42

Photograph 43

Model Closure Section

View from Oregon Shore Cofferdam

Upstream View

Tets 2088
"B" Stone . . . . 27 585 tons
Average Fill Elev . . . 267.0

Photograph 44

Downstream View

Photograph 45

16 November 1950
View from Cell 16

MODEL		PROTOTYPE
2088	Tets	2088
27 585 tons	"B" Stone	27 585 tons

Photograph 46

Photograph 47

18 November 1950

MODEL		PROTOTYPE
2500	Tets	2505
27 585 tons	"B" Stone	27 585 plus 3400 tons "C" Stone
117 000 cfs	River Discharge	117 000 cfs
11 300 cfs	Flow through Fill	10 600 cfs
269.1	Pool Elev	269.1
253.4	Tailwater Elev.	253.4
269.0	Average Fill Elev	

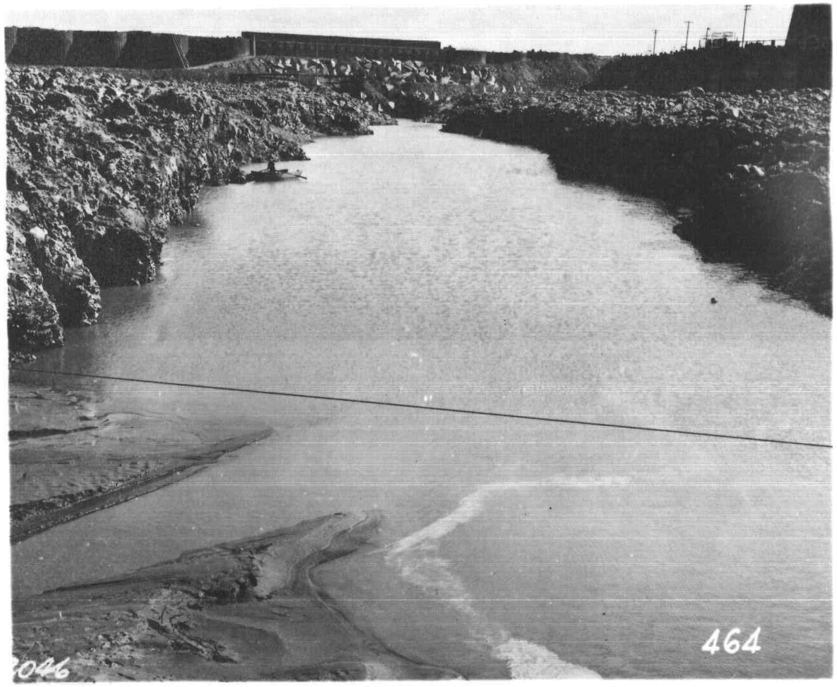
Photograph 48

28 November 1950
3200 Tets

Prototype closure section complete except for timber crib section to be constructed on top of fill.

Photograph 49

Sounding devices used in prototype. Triangular pipe sections in center filled with lead were the most satisfactory of sounding weights tried. A fin was usually affixed to the downstream leg of the triangle.



Photograph 50

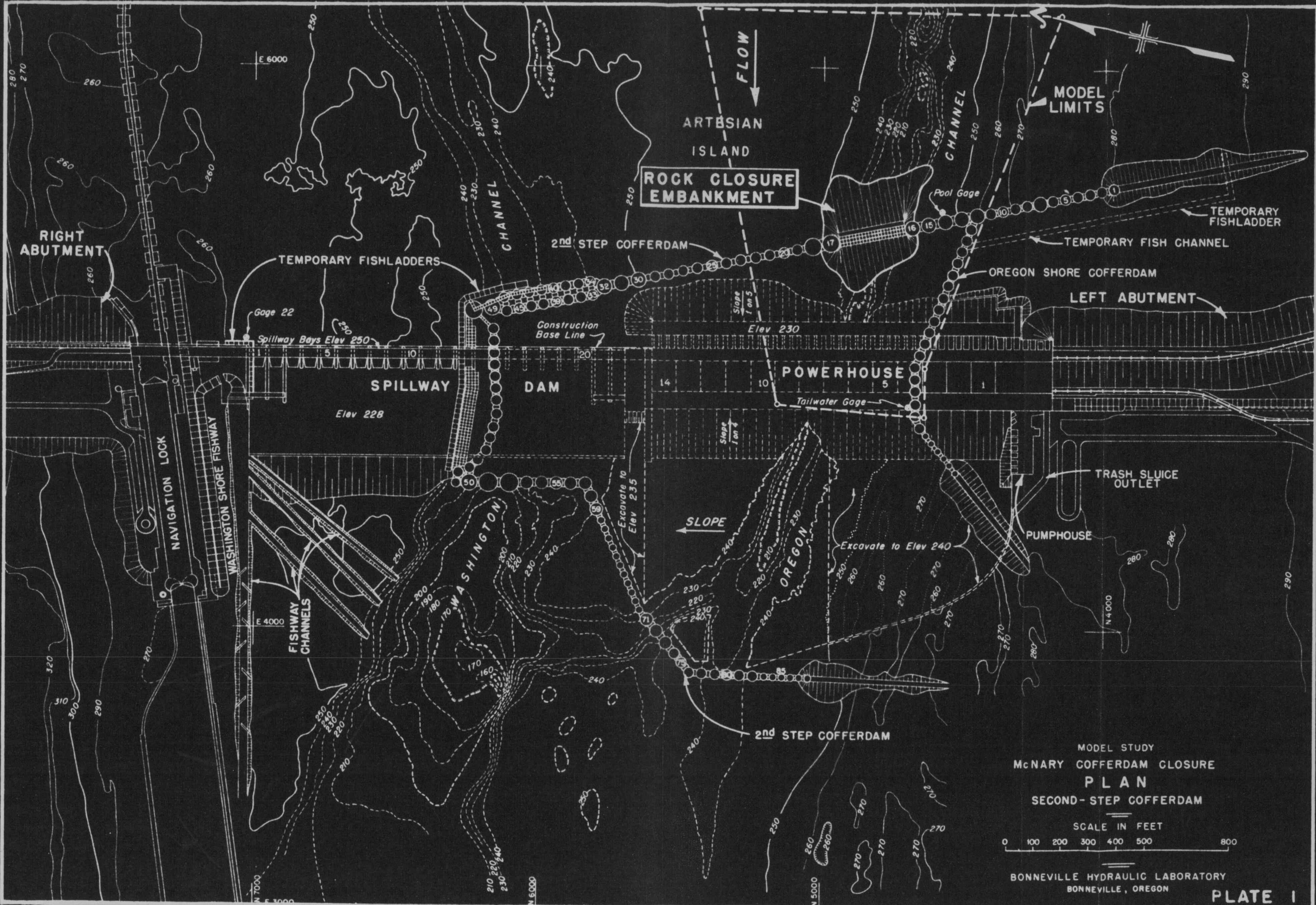
View looking upstream through Oregon channel from downstream leg of second-step cofferdam.

Photograph 51

View of downstream slope of closure section.

Water-Surface Elev 218.4

P L A T E S

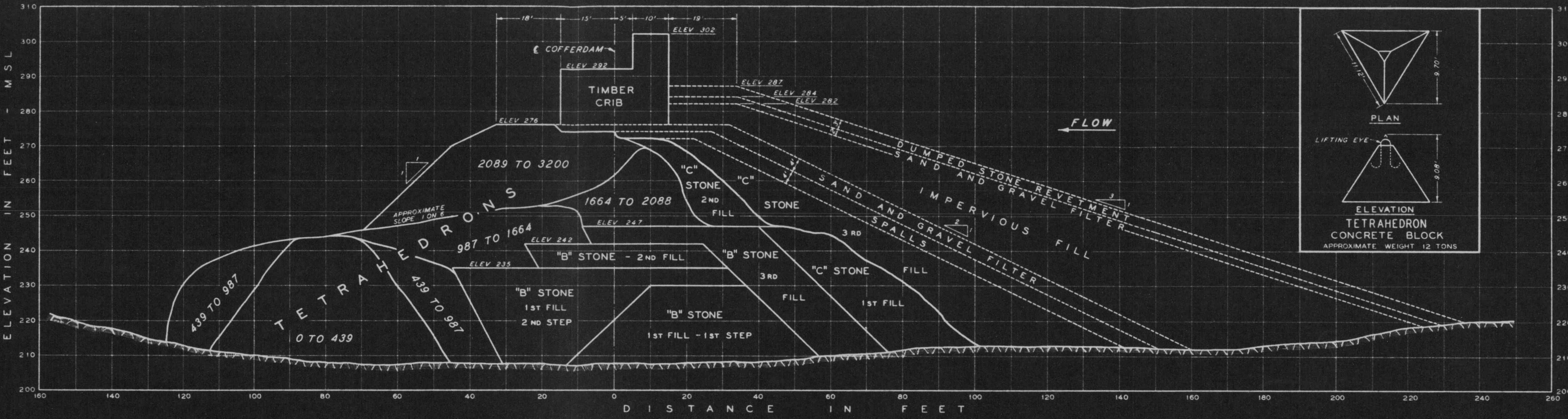


MODEL STUDY
McNARY COFFERDAM CLOSURE
PLAN
SECOND-STEP COFFERDAM

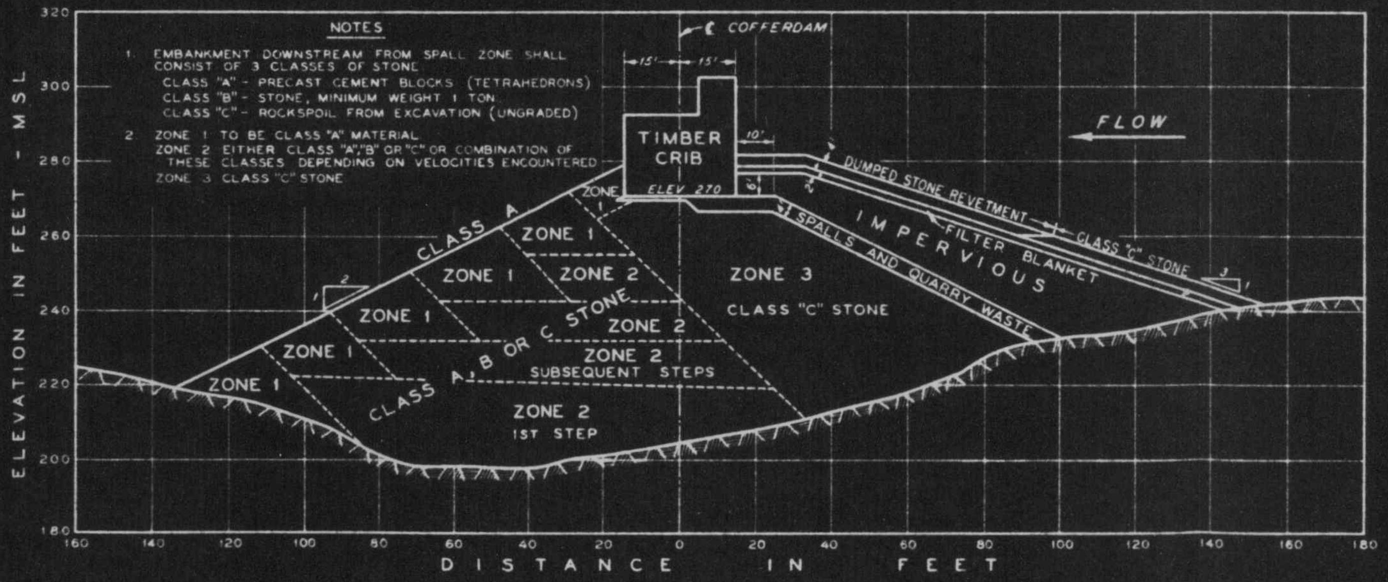
SCALE IN FEET
0 100 200 300 400 500 800

BONNEVILLE HYDRAULIC LABORATORY
BONNEVILLE, OREGON

PLATE 1

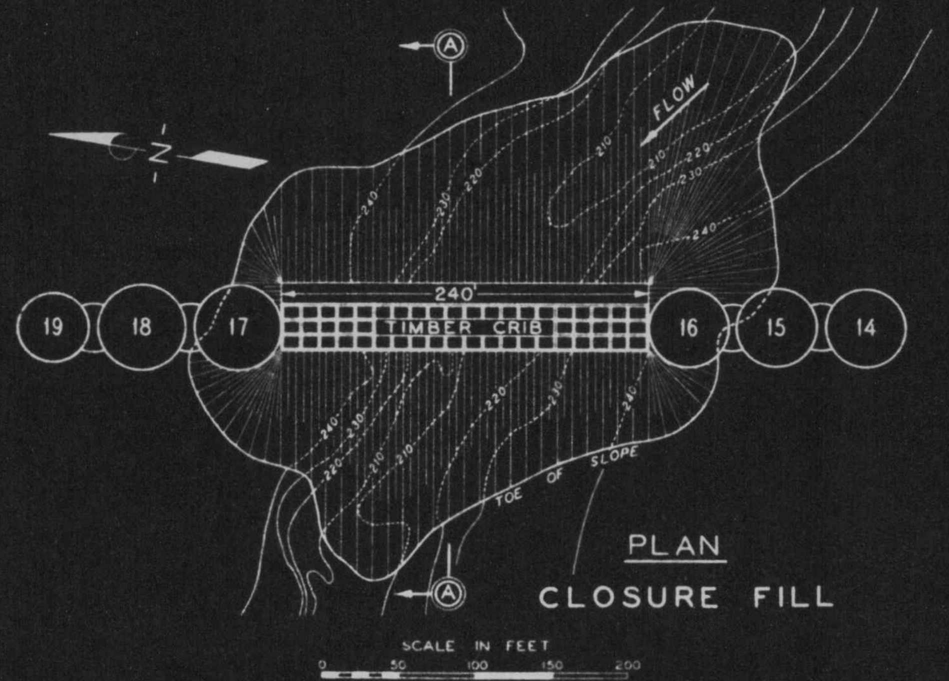


TYPICAL SECTION AS CONSTRUCTED



SECTION A-A

ORIGINAL DESIGN



PLAN

CLOSURE FILL

MODEL STUDY

McNARY COFFERDAM CLOSURE

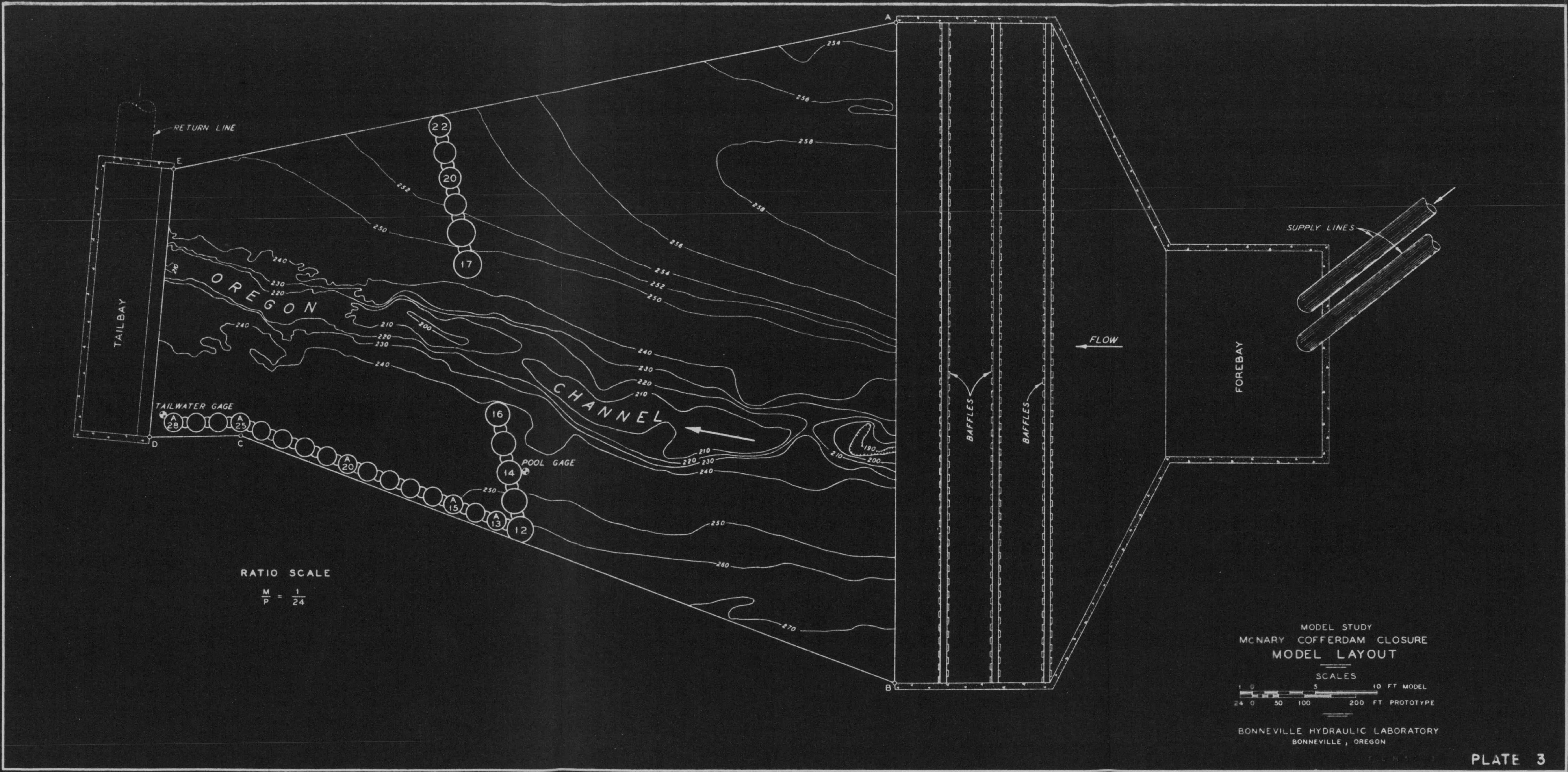
SECOND-STEP CLOSURE FILL

FILL, PLAN, AND SECTIONS

BONNEVILLE HYDRAULIC LABORATORY

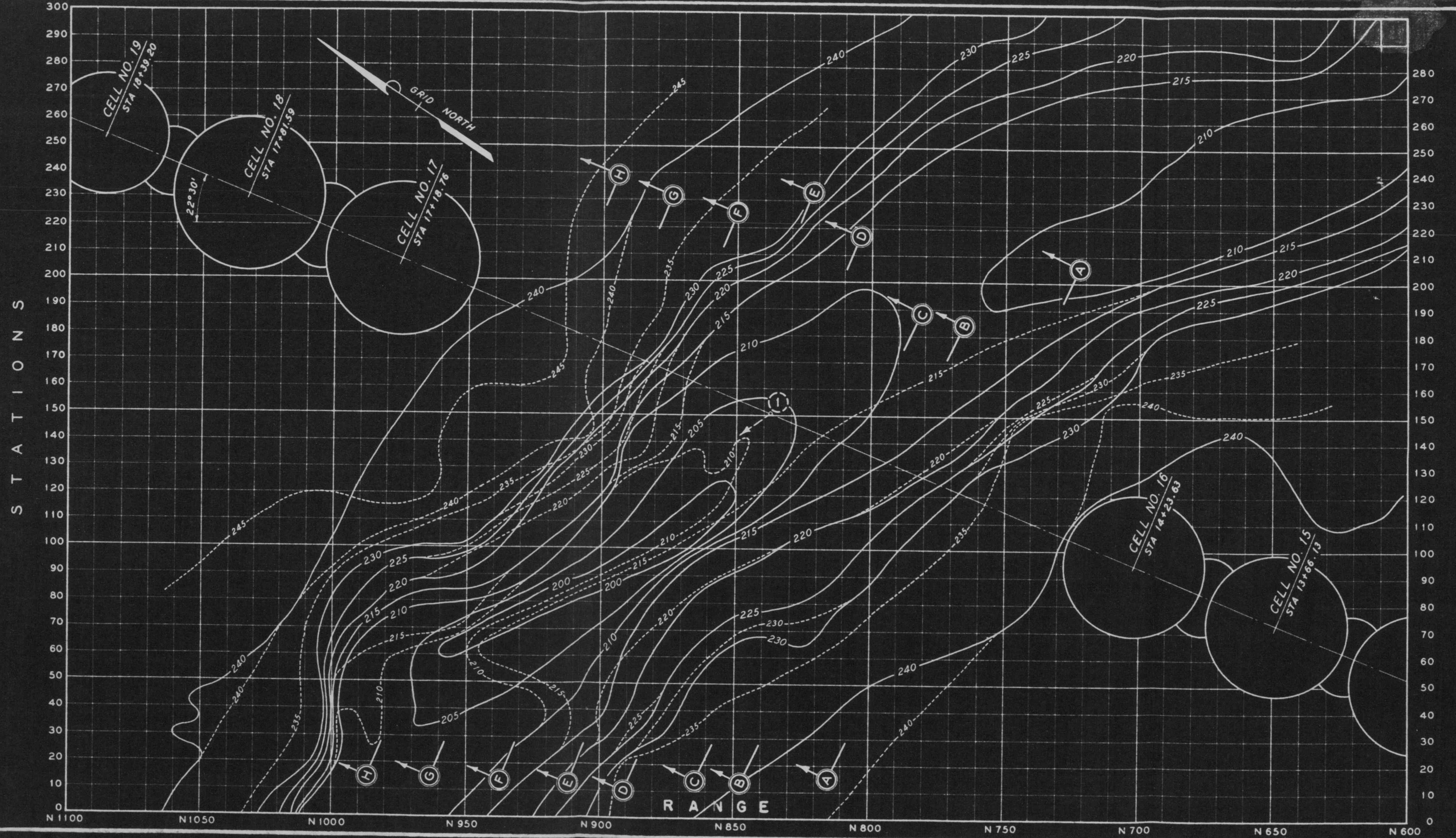
BONNEVILLE, OREGON

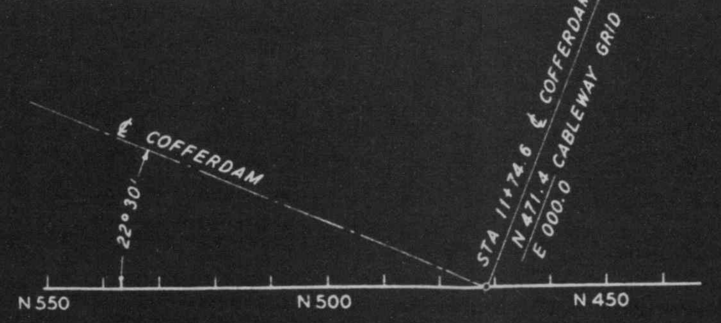
PL 2



RETURN LINE
TAILBAY
OREGON
CHANNEL
TAILWATER GAGE
POOL GAGE
BAFFLES
BAFFLES
FLOW
FOREBAY
SUPPLY LINES
RATIO SCALE
M/P = 1/24
MODEL STUDY
McNARY COFFERDAM CLOSURE
MODEL LAYOUT
SCALES
10 FT MODEL
200 FT PROTOTYPE
BONNEVILLE HYDRAULIC LABORATORY
BONNEVILLE, OREGON

PLATE 3





MODEL VELOCITIES

1

DEPTH FT	V_m
5.0	14.4
10.0	14.2
15.0	13.7
20.0	13.5
25.0	13.5
30.0	13.2
35.0	11.7
40.0	9.8

LEGEND

—220— TESTS 1 TO 5 - MODEL TOPOGRAPHY FROM CORPS OF ENGINEERS SURVEYS OF 1935 AND 1948.

- - -220- - - TEST 6 - MODEL TOPOGRAPHY FROM CORPS OF ENGINEERS SURVEYS OF 1935, 1948, AND OCTOBER 1950.

NOTE

SEE PLATE 5 FOR SECTIONS A-A TO H-H

MODEL STUDY

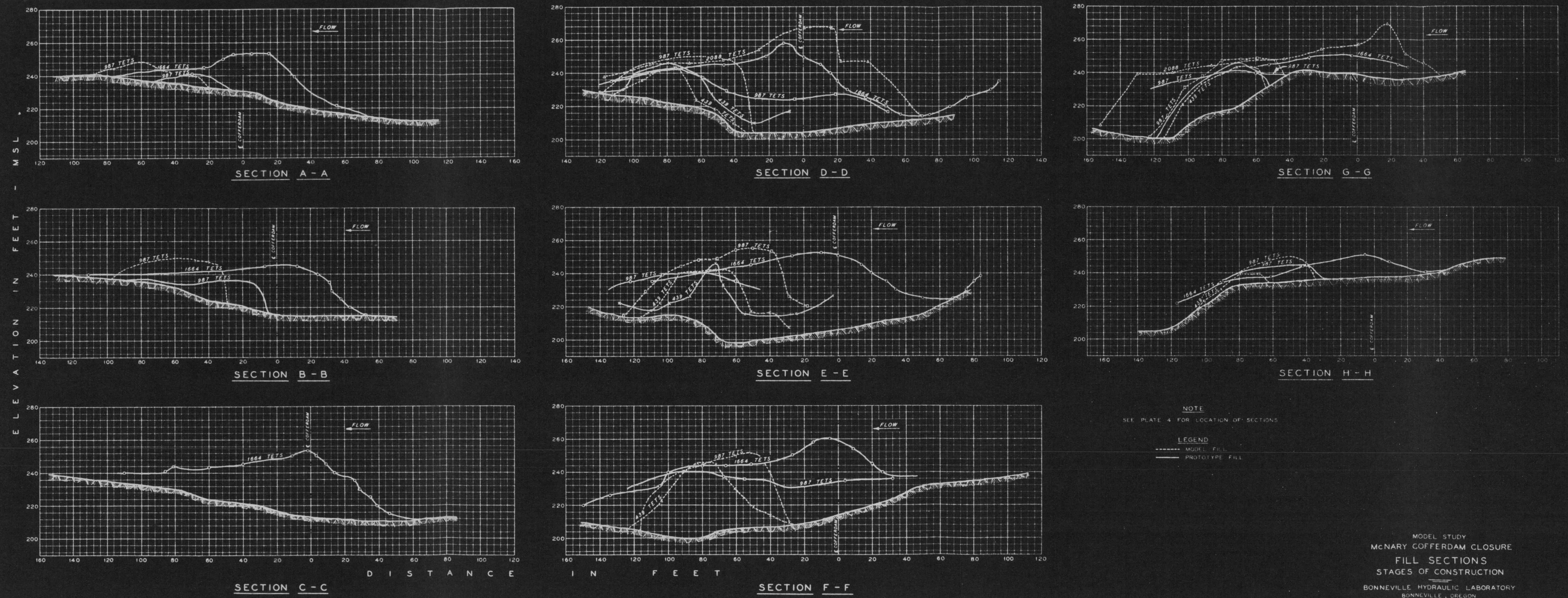
McNARY COFFERDAM CLOSURE

BOTTOM TOPOGRAPHY

CLOSURE SECTION

BONNEVILLE HYDRAULIC LABORATORY
BONNEVILLE, OREGON

PLATE 4



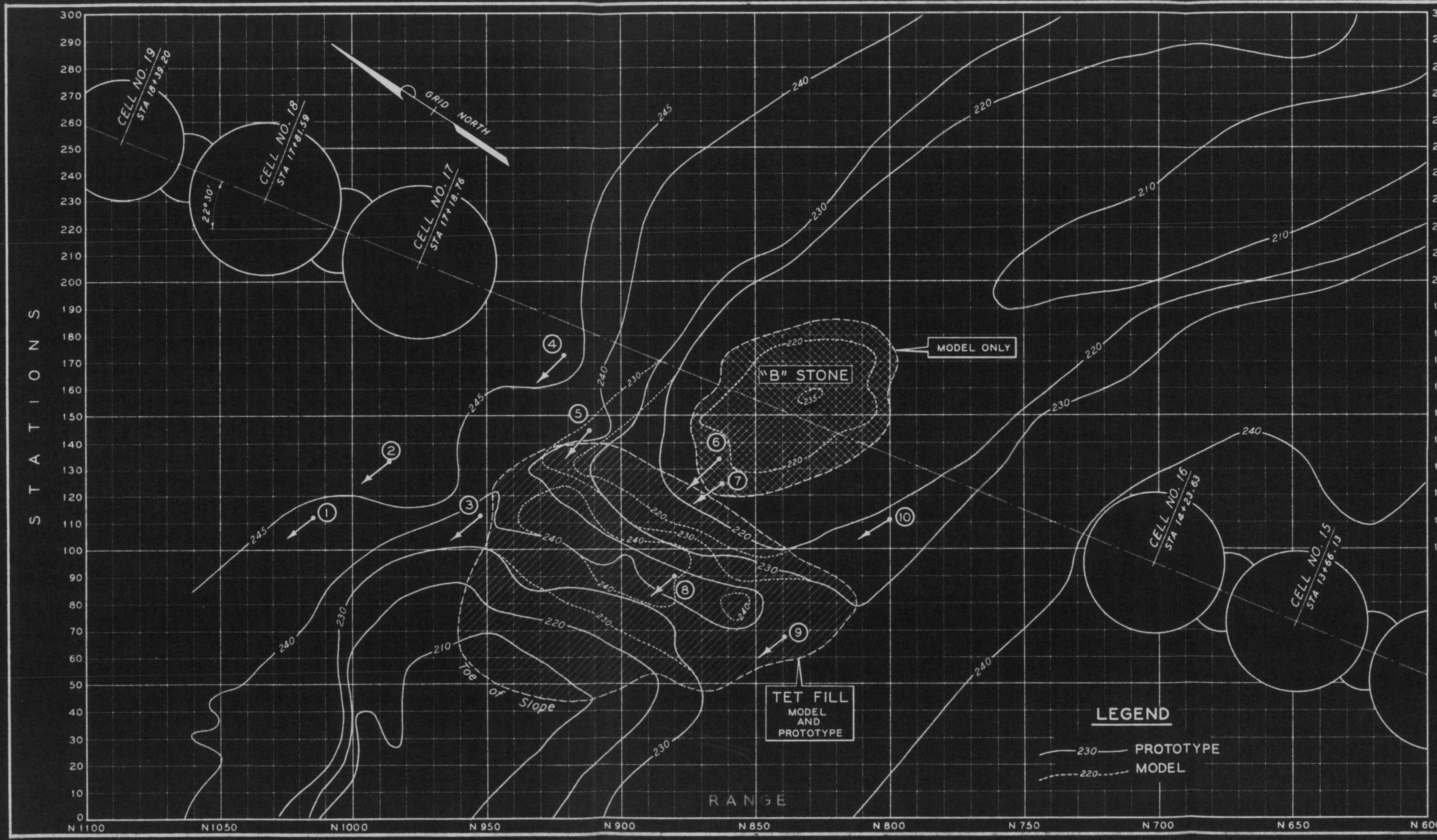
NOTE
SEE PLATE 4 FOR LOCATION OF SECTIONS

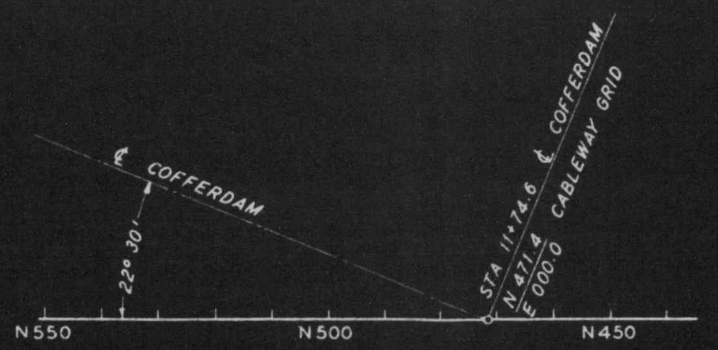
LEGEND
MODEL FILL
PROTOTYPE FILL

MODEL STUDY
McNARY COFFERDAM CLOSURE
FILL SECTIONS
STAGES OF CONSTRUCTION

BONNEVILLE HYDRAULIC LABORATORY
BONNEVILLE, OREGON

PLATE 5





VELOCITIES

1 — Q = 98 000 CFS

DEPTH FT	V_p	V_m
5.0	18.2	15.2

2 — Q = 109 700 CFS

DEPTH FT	V_p	V_m
5.0	17.0	–

3 — Q = 109 700 CFS

DEPTH FT	V_p	V_m
5.0	19.9	–

4 — Q = 98 000 CFS

DEPTH FT	V_p	V_m
5.0	11.0	10.8

5 — Q = 98 000 CFS

DEPTH FT	V_p	V_m
5.0	10.8	11.0

6 — Q = 98 000 CFS

DEPTH FT	V_p	V_m
5.0	9.5	10.9
10.0	9.0	10.8
20.0	8.0	5.4
30.0	5.0	2.0

7 — Q = 98 000 CFS

DEPTH FT	V_p	V_m
2.0	9.3	10.9
12.0	9.9	9.3
22.0	8.8	12.5
30.0	6.0	–

8 — Q = 109 700 CFS

DEPTH FT	V_p	V_m
5.0	12.2	–
10.0	13.7	–
15.0	14.6	–

9 — Q = 109 700 CFS

DEPTH FT	V_p	V_m
5.0	17.0	–
10.0	17.0	–
15.0	16.3	–

10 — Q = 98 000 CFS

DEPTH FT	V_p	V_m
5.0	11.5	12.0
10.0	11.6	12.5
15.0	10.9	12.5
20.0	7.9	12.5

NOTES

1. PROTOTYPE SURVEY OF OCTOBER 13, 15, AND 22, 1950.
2. DISCHARGES SHOWN ARE TOTAL RIVER DISCHARGES.

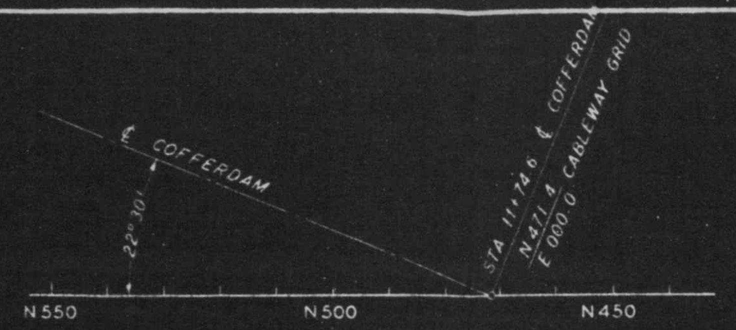
MODEL STUDY

McNARY COFFERDAM CLOSURE

MODEL AND PROTOTYPE FILLS

439 TETS AND 2267 TONS "B" STONE

BONNEVILLE HYDRAULIC LABORATORY



PROTOTYPE VELOCITIES

①

DEPTH FT	V_p
5.0	16.6
15.0	20.2

②

DEPTH FT	V_p
5.0	14.3
10.0	14.3

③

DEPTH FT	V_p
5.0	15.3
15.0	16.6

④

DEPTH FT	V_p
5.0	14.9
10.0	14.6
15.0	14.6

⑤

DEPTH FT	V_p
5.0	8.3
10.0	8.1
15.0	7.6

⑥

DEPTH FT	V_p
5.0	14.9
15.0	13.7

⑦

DEPTH FT	V_p
5.0	17.0
10.0	19.3

MODEL VELOCITIES

①

DEPTH FT	V_m
5.0	24.5
10.0	20.6
15.0	5.4

②

DEPTH FT	V_m
5.0	12.7
10.0	11.8
15.0	12.7

③

DEPTH FT	V_m
5.0	13.2
10.0	13.2
15.0	9.8

④

DEPTH FT	V_m
5.0	7.4
10.0	8.3
15.0	8.3

NOTE

PROTOTYPE SOUNDINGS AND VELOCITIES MEASURED 5 NOVEMBER 1950.

MODEL STUDY

McNARY COFFERDAM CLOSURE

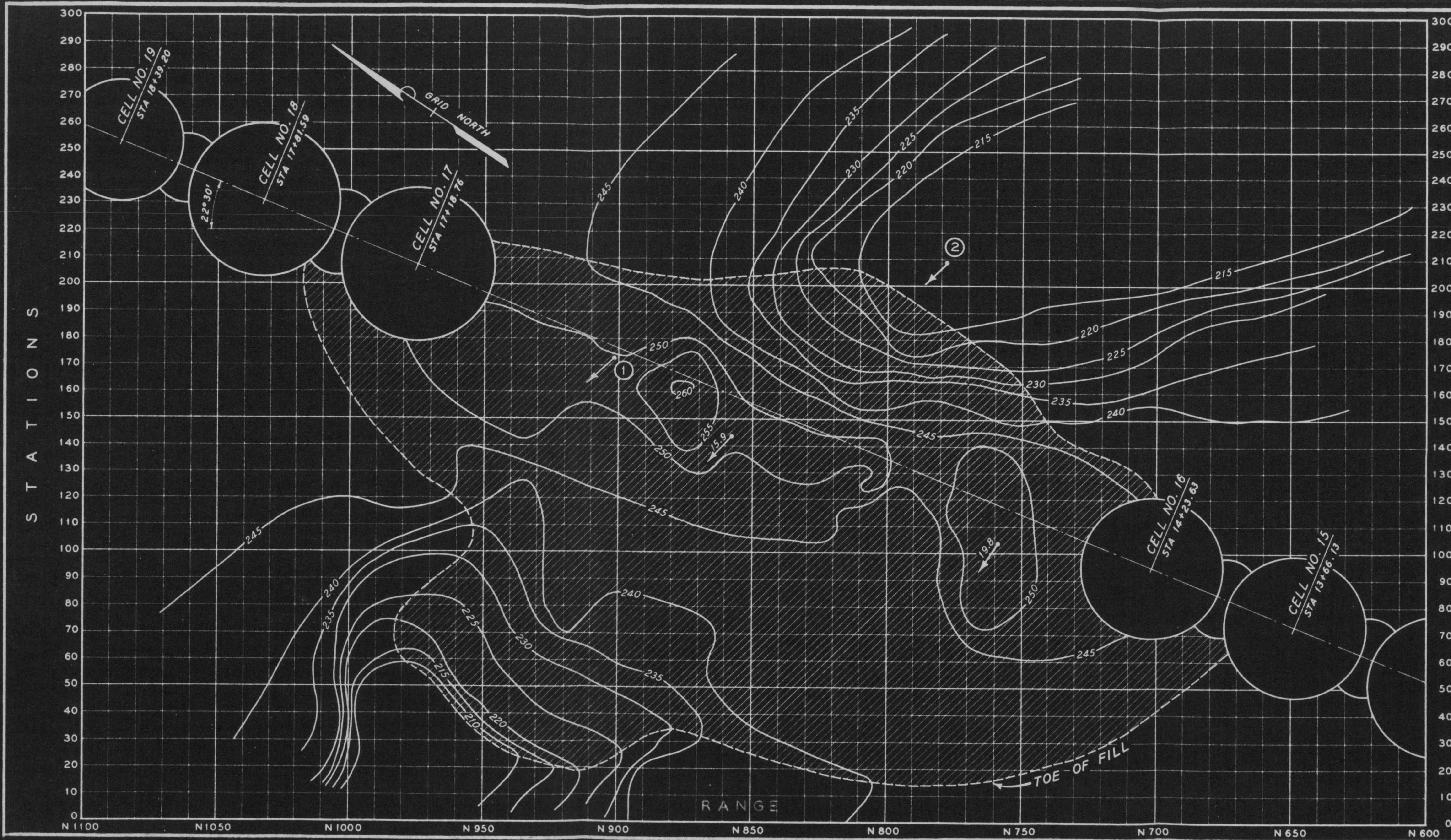
MODEL AND PROTOTYPE FILLS

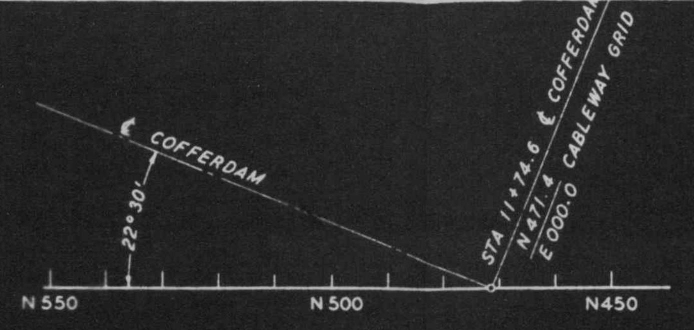
987 TETS AND 8427 TONS "B" STONE

RIVER DISCHARGE 153 000 CFS

BONNEVILLE HYDRAULIC LABORATORY
BONNEVILLE, OREGON

PLATE 7





VELOCITIES

①

DEPTH FT	Vp
5.0	12.9
10.0	14.3
15.0	13.1

②

DEPTH FT	Vp
5.0	3.7
25.0	3.9

NOTE

PROTOTYPE SOUNDINGS AND VELOCITIES MEASURED 12 NOVEMBER 1950.

MODEL STUDY

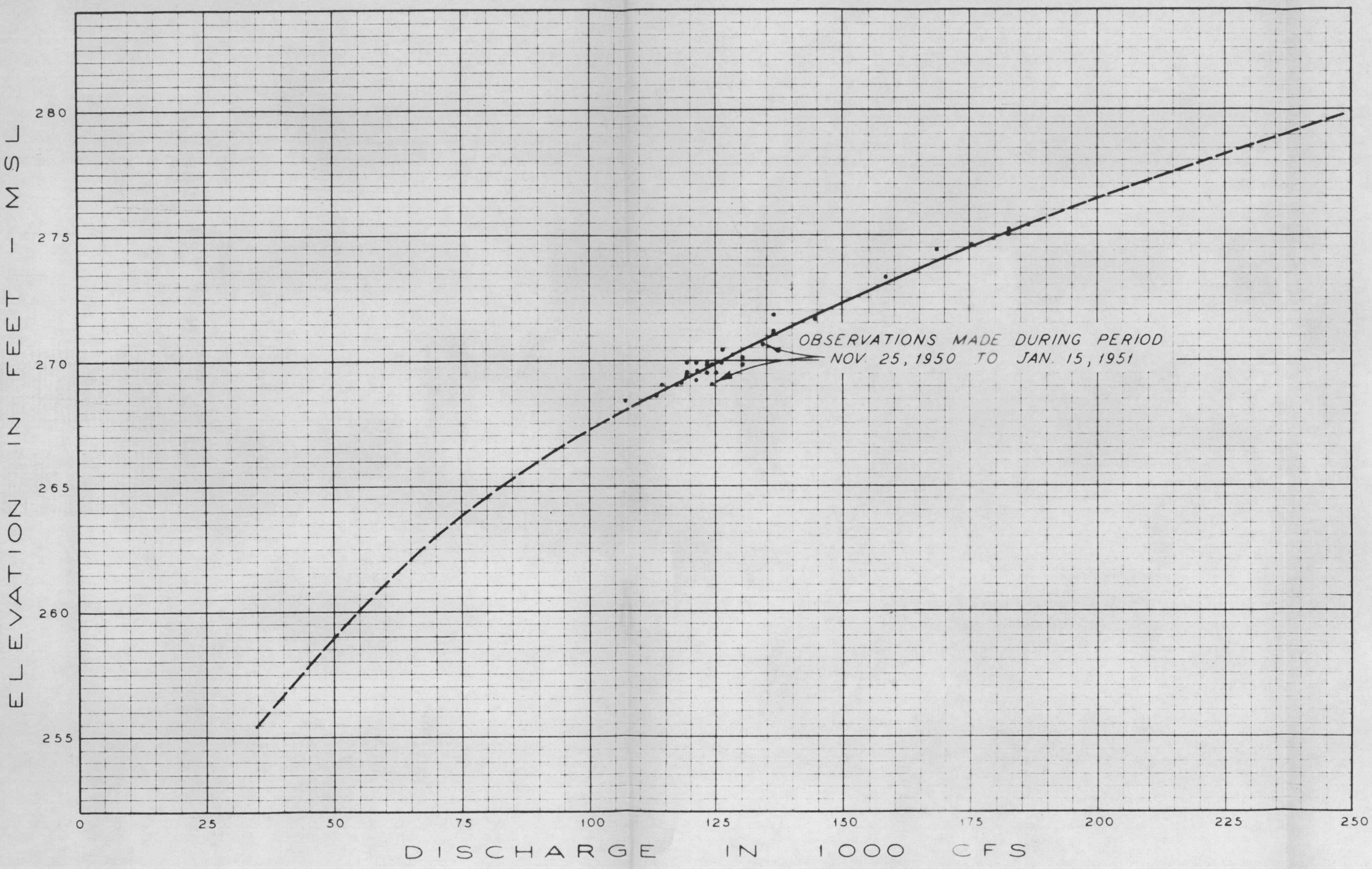
McNARY COFFERDAM CLOSURE

MODEL AND PROTOTYPE FILLS

1664 TETS AND 20 309 TONS "B" STONE

RIVER DISCHARGE 124 000 CFS

BONNEVILLE HYDRAULIC LABORATORY PL 8



NOTES

1. McNARY SECOND-STEP COFFERDAM COMPLETED AT TIME OF OBSERVATIONS.
2. GAGE 22 LOCATED AT UPSTREAM END OF TEMPORARY FISHLADDER IN BAY 1 OF SPILLWAY (PLATE 1)
3. SPILLWAY CONSISTED OF 12 BAYS (ELEV 250) WITH TEMPORARY FISHLADDER LOCATED IN BAY 1

MODEL STUDY

McNARY COFFERDAM CLOSURE

RATING CURVE

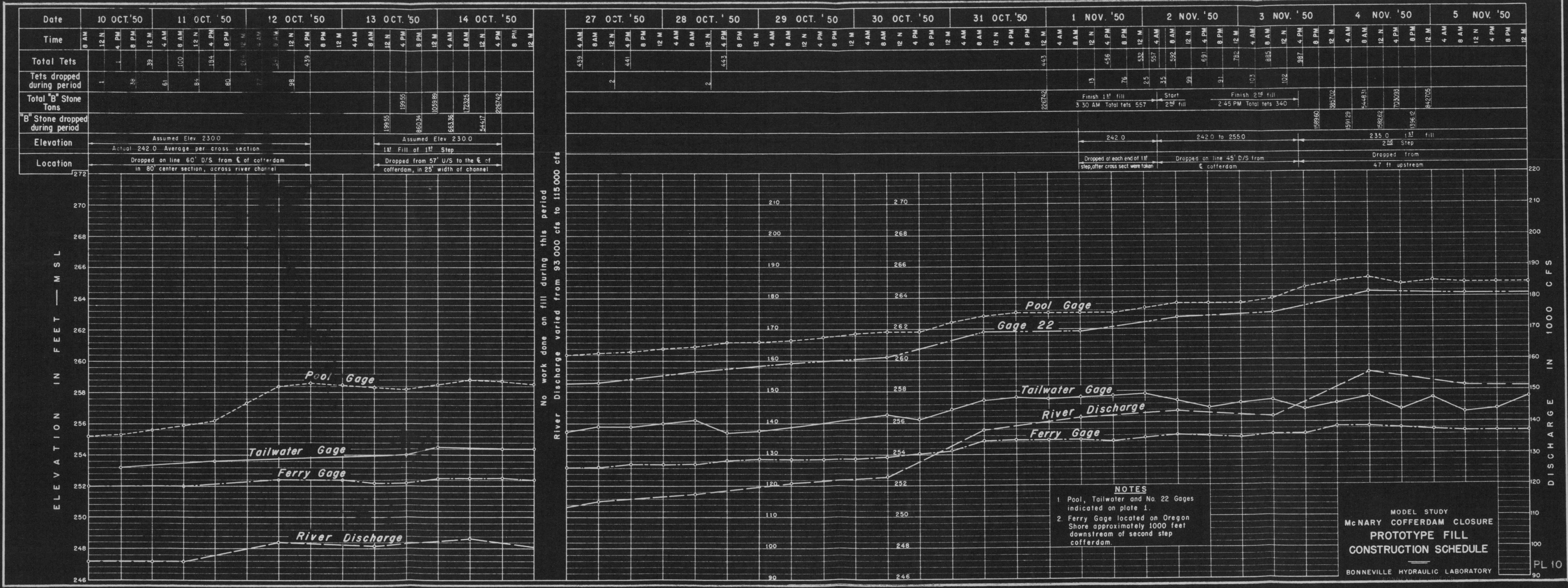
PROTOTYPE SPILLWAY DISCHARGE

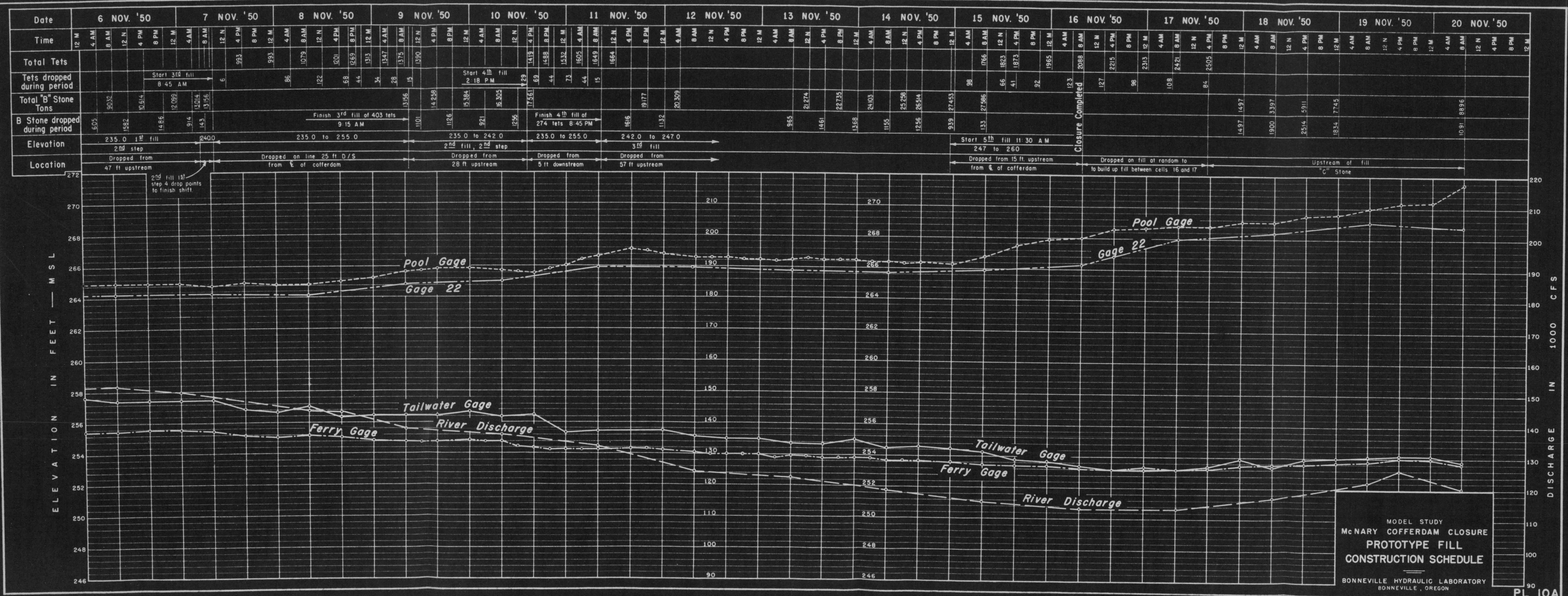
GAGE 22

BONNEVILLE HYDRAULIC LABORATORY

BONNEVILLE, OREGON

PLATE 9


Date
10 OCT. '50
11 OCT. '50
12 OCT. '50
13 OCT. '50
14 OCT. '50
27 OCT. '50
28 OCT. '50
29 OCT. '50
30 OCT. '50
31 OCT. '50
1 NOV. '50
2 NOV. '50
3 NOV. '50
4 NOV. '50
5 NOV. '50
Time
Total Tets
Tets dropped during period
Total "B" Stone Tons
"B" Stone dropped during period
Elevation
Location
Assumed Elev 230.0
Actual 242.0 Average per cross section
Dropped on line 60' D/S from ℄ of cofferdam in 80' center section, across river channel
Assumed Elev 230.0
1st Fill of 1st Step
Dropped from 57' U/S to the ℄ of cofferdam, in 25' width of channel
No work done on fill during this period
River Discharge varied from 93 000 cfs to 115 000 cfs
Finish 1st fill 3:30 AM Total tets 557
Start 2nd fill
Finish 2nd fill 2:45 PM Total tets 340
242.0
242.0 to 255.0
235.0 1st fill
2nd Step
Dropped at each end of 1st step, after cross sect were taken
Dropped on line 45' D/S from ℄ cofferdam
Dropped from 47 ft upstream
ELEVATION IN FEET — MSL
DISCHARGE IN 1000 CFS
Pool Gage
Gage 22
Tailwater Gage
Ferry Gage
River Discharge
NOTES
1. Pool, Tailwater and No. 22 Gages indicated on plate 1.
2. Ferry Gage located on Oregon Shore approximately 1000 feet downstream of second step cofferdam.
MODEL STUDY
McNARY COFFERDAM CLOSURE
PROTOTYPE FILL
CONSTRUCTION SCHEDULE
BONNEVILLE HYDRAULIC LABORATORY
PL 10



MODEL STUDY
McNARY COFFERDAM CLOSURE
PROTOTYPE FILL
CONSTRUCTION SCHEDULE

BONNEVILLE HYDRAULIC LABORATORY
BONNEVILLE, OREGON

PL 10A