W. L. Cook

PROVINCE OF MANITOBA
DEPARTMENT OF AGRICULTURE AND CONSERVATION
WATER CONTROL AND CONSERVATION BRANCH

Red River Floodway

REPORT

on

HYDRAULIC MODEL TESTS OF THE OUTLET CONTROL WORKS

H. G. ACRES & COMPANY LIMITED
Consulting Engineers
Niagara Falls, Canada

December 1962

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1 - Summary

This report presents the results of hydraulic model tests which were carried out on a model of the outlet control works, and which showed that:

(a) - An artificial stilling basin is not required, as bedrock is located at an elevation that allows a hydraulic jump to form with natural tailwater levels.

(b) - Economies can be realized in the design of the training walls for the structure by increasing the slope protection of the bordering dykes.

(c) - Adequate control of upstream water levels can be achieved by constricting the channel at the control structure to a width of 162 feet.

(d) - By correct shaping of the outlet channel, the velocity distribution across the Red River, below the confluence with the floodway, can be made to conform essentially to natural conditions.

The recommended configuration of the upstream and downstream channels, the shape of the structure, and the requirements for slope protection are shown on Plate 1, and in the data presented in Tables VI and VIII.

2 - Statement of the Problem

The purpose of the Red River Floodway, in conjunction with other flood control measures, is to protect the Greater Winnipeg area from the consequences of all but the most infrequent floods. This will be achieved by diverting a substantial part of flood flows from the Red River into the floodway channel approximately one mile south of the Village of St. Norbert. This channel will convey the water to the north of the city and deposit it back into the main river channel approximately one-half mile north of the St. Andrews control dam at the Village of Lockport.

To provide an economic non-scouring, non-depositing, unlined channel some 29 miles in length, it has been necessary to adopt a lesser gradient than exists in the corresponding reach of the Red River. The diverted flows, therefore, will arrive at the confluence with greater potential energy than the undiverted flows in the Red River. The purposes of the outlet control works are to dissipate this additional energy so that the rate of erosion in the Red River, below the confluence with the floodway, will not be increased beyond that which would occur under natural conditions; and to maintain water levels in the floodway channel so that velocities will not exceed five feet per second up to design flood conditions. This velocity is considered to be the no-scour, no-deposit velocity for the channel.

The outlet control works will occupy a reach of about 1,800 feet between station -14+00 on the floodway centreline and the Red River. The complicated velocity distribution which will occur downstream from the confluence cannot be accurately predicted by analytical methods and, therefore, a moveable-bed hydraulic model of the outlet control works area was constructed at the University of Manitoba. Detailed studies were carried out on this model to determine the most economic combination of structure and channels which would meet the design requirements.

Testing of a preliminary design commenced in January 1962, and was completed in May 1962. Following adjustments to conform to the final floodway channel design, a revised design of the structure and channel was tested between August and October 1962.

The basic requirements and conditions to be met by the outlet control works have been defined by the Floodway Division, and are:

(a) - The dissipation of destructive kinetic energy up to the design flood discharge of 60,000 cfs in the floodway channel is to be ensured.

(b) - The flow conditions are to be those which may occur with all flood control works in operation. These include the Shellmouth Reservoir and Portage Diversion, in addition to the Red River Floodway. The range of flow conditions to be considered has been defined as those combinations of flood flows in the Red River and the Assiniboine River which will occur 90 per cent of the time.

(c) - Conduits are to be provided through the outlet structure to pass up to 100 cfs with a maximum headwater elevation of 726.2 at the beginning of the upstream transition channel.

An additional requirement which influenced the initial design was that the control structure should withstand a discharge of 100,000 cfs which may result either from the occurrence of the 1,000-year flood, or from other conditions of emergency operation resulting in overloading of the floodway at lower flood discharges. This requirement was subsequently modified as it was considered unnecessary to provide normal safety factors in the design of the structure for such infrequent occurrences. However, further testing was undertaken at this flow to evaluate the stability of the structure, as designed for 60,000 cfs, under this extreme overload condition.

It is considered that effective energy dissipation will have been achieved if the velocity distribution in the Red River immediately below the confluence with the floodway is substantially unaltered from that which would occur under natural conditions.

Analytical studies resulted in a basic arrangement for the outlet control works model as shown on Plate 2. The model test program provided information from which to assess the hydraulic efficiency and economy of several elements of the design. These included:

(a) - The configuration of the upstream wing walls and approach channel to the rollway.

(b) - The shape of the rollway.

(c) - The effect on stilling action caused by varying the stilling basin length.

(d) - The shape of the training walls.

(e) - The shape of the downstream wing walls.

(f) - The effect of varying the outlet channel configuration on the scour action in the channel.

(g) - The requirement for riprap through the upstream transition and the outlet channel.

3 - Description of the Model

The model was constructed to a scale ratio of 1:100 and included a reach of the Red River extending approximately 2,000 feet upstream and 1,200 feet downstream from its confluence with the floodway channel, together with 2,000 feet of floodway channel.

As shown on Plate 2, certain sections of the model were moveable, the bed load material being composed of sieved mortar sand; the remaining sections were modelled in cement mortar laid over a well-compacted sand base. The moveable sections were moulded, using surface templates spaced at approximately 200-foot intervals. The fixed bed sections were carefully trowelled to base templates. All templates accurately defined the topography to ± 1 foot in the steep riverbank areas and to ± 0.5 foot both in the flatter areas of the riverbed and the surrounding prairie.

A moveable bed was used in this model to provide information as to the location and depth of scour likely to develop in the prototype when the unprotected outlet channel was subjected to high-velocity floodway flows. Grading curves of the moveable-bed materials tested are shown on Plate 3.

Material "A" was tested initially as its scour velocity in the model was similar to the expected scour velocity of the materials making up the prototype channel. However, it was found that the particles composing it were of such a size that excessive rippling of the bed developed. As the formation of ripples and sand dunes would seriously distort flow conditions in a model of this scale, material "B" was tested in an attempt to rectify this problem.

Although material "B" markedly reduced the amount of rippling, it still contained an excess of fines and prevented the development of stable scour patterns. Material "C" was manufactured by passing material "B" through a one-millimetre screen to remove the fines. The test results achieved using material "C" were considered adequate as:

(a) - The mean particle size approximated the expected prototype roughness (Manning's "n" = 0.028).

(b) - The majority of particles were of sufficient magnitude to prevent the formation of ripples and sand dunes.

(c) - Although the scour velocity of this material was in excess of five feet per second, it was found that it eroded at sufficiently low velocities to allow determination of areas subject to serious scour. This higher scour velocity proved of advantage in determining the most suitable outlet channel configuration, as scour results in combination with velocity traverses clearly showed that bank protection would result in marked savings in excavation.

The rollway consisted of a solid block of lacquered wood, while the wing walls and stilling basin apron were constructed of treated 1/2-inch plywood. The dykes bordering the structure were constructed of concrete to form an impermeable bulkhead between the upstream and downstream channel sections.

Water was supplied to the floodway and Red River sections of the model from a constant head tank through two rectangular head boxes containing rock baffles and 90-degree, V-notch measuring weirs. In each case, the rock baffles were designed to minimize surges and to ensure both accurate discharge measurements and an even flow distribution to the upstream sections of the floodway and river channel. After leaving the model, the water passed over a sand trap and over an adjustable tail gate, which was used to accurately control water levels in the model, before returning to the sump for recirculations.

The ratios for the transfer of model data to the prototype, by Froude similitude, are as follows:

Length	1:100	= 1/100
Volume	$1:100^3$	= 1/1,000,000
Discharge	$1:100^{5/2}$	= 1/100,000
Velocity..........	$1:100^{1/2}$	= 1/10

4 - Test Procedure and Program

Testing of the outlet control works model was carried out in two stages. Before final details of the floodway channel were known, an interim design of the outlet control structure, designated model "A", was tested. For these tests, a rollway 162 feet wide was selected as a result of analytical studies. The rollway was connected to a stilling basin, 136 feet long, located between vertical and parallel training walls. The test program was arranged so that the effect of altering various sections of the model could be studied independently. The various designs tested in this first model are summarized in Table I.

After the design of the floodway channel had been established, minor changes were made to the control structure to comply with changes in the channel shape, gradient, and water levels. This design is referred to as model "B", and the various modifications tested are described in Table II.

Due to the proposed method of operating the floodway in conjunction with the storage and diversion works planned for the Assiniboine

River, it was necessary to test the outlet structure for various combinations of flows in the floodway and the Red River, as given in Table III.

For each test the following measurements were made:

(a) - Discharge measurements for the floodway and the Red River.

(b) - Measurements of the water surface were completed along the structure centreline from 500 feet upstream from the structure to 300 feet downstream from the rollway at sufficient spacing to define the upstream profile and downstream wave heights, to provide a rating curve for the structure, and to aid in the structural design of the training walls.

(c) - Point velocity traverses at 0.6 of the water depth using a pigmy meter, and within one-half inch of the bottom using a Bentzel tube, were completed at sufficient intervals to allow the development of detailed velocity distribution patterns upstream and downstream from the structure and in the Red River below its confluence with the floodway. These data were obtained to determine riprap requirements and basic flow criteria.

(d) - Flow patterns were developed in the outlet channel and in the Red River using dye tracers to assess the smoothness with which the floodway flows merged with those of the Red River.

(e) - Contours were laid at 10-foot intervals, before and after each test which resulted in scour, through the outlet channel and in the Red River to record the location and extent of scour.

5 - Analysis of Results and Recommendations

A summary of all tests completed on the outlet control works model is contained in Table IV. For convenience, the outlet control works are discussed hereunder in the several sections which, although interdependent, were subject to separate modification throughout the course of the test program.

5.1 - The Upstream Transition Channel - Only one basic configuration of the upstream transition channel, as shown on Plate 2, was tested. However, the effect of different bank slopes was examined and, as may be seen from the test results given in Table V, these do not significantly affect the upstream water level at design flood.

As any of the variations tested may be considered hydraulically satisfactory, it was concluded that the bank slopes should be maintained at 6:1 for the initial 385 feet to minimize problems associated with the stability of slopes of in-situ materials. The slopes in the final 100 feet of the transition vary rapidly from 6:1 to 2:1 as the channel converges upon the structure.

Velocity traverses completed through the transition area verified that the shape was effective in producing uniform acceleration of the floodway waters, and provided data for the determination of riprap sizes to protect the transition surfaces against scour. The required riprap sizes and their locations are tabulated in Table VI and shown on Plate 1.

5.2 - The Upstream Wing Walls and Approach Channel - The criteria for the outlet control works structure include the requirement that for design flow conditions of 60,000 cfs in the floodway, water levels at the start of the upstream transition should not exceed elevation 752.2. In addition, model "A" was tested for the floodway capacity discharge of 100,000 cfs, at which stage upstream water levels were not to exceed elevation 762.0. The headwater levels for the various wing wall and approach channel shapes tested are summarized in Table VII.

From the test results, it is readily seen that increasing the radius of the upstream wing walls does not result in a marked reduction in headwater levels. In addition, eliminating the approach channel tends to increase upstream water levels by preventing the contracted flow from expanding to the full width of the rollway.

As shown in Table VII, essentially the same upstream water level occurs with either a 25-foot radius wing wall as with the combination of an 11-foot radius wing wall and a 16.5-foot approach channel. As the latter arrangement permits considerable structural economy, it is preferred.

The crest of the wing walls must be not lower than elevation 753.0. Although freeboard of 0.8 feet over design flood level is nominal, it is not anticipated that there will be any significant wave set-up in the floodway channel. Therefore, upstream wing walls at elevation 753.0 are considered satisfactory.

5.3 - The Rollway - The significant change in rollway shape between model "A" and model "B", as shown on Plate 4, resulted from considerations of structural stability. The additional mass necessary allowed sloping of the upstream face of the ogee. However, the theoretical increase in discharge coefficient caused by sloping the upstream face was offset by changes in the shape of the floodway and transition channels, thereby leaving the structure width of 162 feet unchanged. On Plate 5, the final rating curve for the structure as determined from model "B" is presented.

The rollway, as shown on Plate 1, will have a 1:1 upstream face, and the crest will be at elevation 730.0. The shape, as tested, proved to be hydraulically efficient.

Although not tested, two 42-inch diameter conduits have been provided through the rollway to accommodate discharges of up to 100 cfs from the low flow pilot channel.

5.4 - The Stilling Basin - Plates 6 and 7 show the water surface profiles through the two structures for the various stilling basin lengths tested. Tests were completed using an apron level of 708.0 feet for model "A" and 707.5 feet for model "B". Aprons placed at these elevations result in a factor of safety of approximately 1.1 over the theoretical conjugate jump depth at design flow. The water surface profiles show that, with the outlet channel excavated to bedrock, eliminating the chute blocks and changing the location of the end sill does not materially affect the location or height of the hydraulic jump, nor the height of the downstream surface waves. This is due to the fact that with bedrock at approximately elevation 708.0 and with natural tailwater levels, a hydraulic lump will form without the use of an end sill or chute blocks.

However, because of the high velocities which still exist in the stilling area, it is recommended that an apron slab be placed for the full length of the training walls to protect against undercutting which could result from erosion of the unprotected bedrock.

Photographs No. 1 and No. 2 show the initial and final configurations respectively of the stilling area. Photographs No. 3 and No. 4 show the downstream surface turbulence for 19-foot and 0-foot stilling basins respectively.

5.5 - The Training Walls - Training walls, when shaped to contain the high velocity flows from the spillway, extend the influence of these supercritical flows some distance downstream, thereby delaying the formation of a hydraulic jump. On the other hand, comparing tests 82 and 86 on Plate 6, sloping of the training walls allows downstream water levels to impose their influence on the high velocity flows at an earlier stage, thereby resulting in essentially the same energy dissipation over a much shorter distance.

However, reducing the horizontal crest length of the training walls to less than 36 feet and sloping the downstream section at 2:1 rather than 2.5:1, although not seriously affecting the location of the jump, did result in reduced energy dissipation and distorted downstream velocity distributions. This was due to the development of extremely strong return currents along both banks which entered the stilling area and seriously contracted the flow immediately below the rollway.

The final shape of the training walls, as shown on Plate 1, was determined by an economic study which compared the reduction in training wall section with the increase in riprap size required to protect the downstream dyke slopes for those shapes which did not distort downstream flow patterns.

The differences between the training walls for model "A" and model "B", as shown on Plates 6 and 7, are due to changes in the design criteria. Model "A" was designed to contain a flow of 100,000 cfs, whereas model "B" was designed to protect for a maximum flow of 60,000 cfs only.

<u>5.6 - The Downstream Wing Walls</u> - Downstream wing walls are normally provided for the following reasons:

(a) - Where the channel downstream from a stilling basin is composed of erodible material, wing walls are provided to prevent undercutting and possible failure of the dyke slopes.

(b) - Where the required stilling basin length would fall inside the base length of the dykes, wing walls are provided to ensure dyke stability.

In the case of the outlet control works, the invert of the outlet channel is at bedrock. The downstream wing walls, as shown on Plate 1, are required only to ensure dyke stability as the training walls are terminated before the dyke slopes intersect the invert of the outlet channel.

5.7 - Configuration of the Outlet Channel - As the length of the stilling basin had only a small effect on the amount of energy dissipated, the outlet channel was considered as an independent variable. The criteria affecting the outlet channel design are:

(a) - The floodway flows must merge smoothly with the Red River flows.

(b) - The velocity distribution in the Red River below the confluence must be substantially unaltered from that which would occur under natural conditions.

Plate 8 shows the velocity distributions in the Red River approximately 520 feet, 920 feet and 1,400 feet downstream from the intersection of the structure centreline with the thalweg of the Red River for various outlet channel configurations. It will be noted from these curves, as determined in the model, that natural flow conditions are essentially duplicated at all three sections with a number of designs. The final configuration, as shown on photographs No. 5 and No. 6 and on Plate 1, was that design which satisfied the criteria and proved to be the most economical.

In the outlet channel, as through the upstream transition, velocity traverses were used to determine riprap requirements. These measurements, in conjunction with flow patterns, showed that the path followed by the high velocity flows emitting from the rollway was not fixed but oscillated to each side of the centreline. This slow period motion was particularly noticeable when floodway flows were allowed to vary slightly from the specified test figures. This flow condition dictates the need for protection of both banks of the outlet against scour action. The recommended riprap sizes and their locations are tabulated in Table VIII.

It may be noted that riprap protection is extended to cover the projecting nose of the west bank of the channel on the river slope side between elevation 710 and elevation 738. It was observed in the model that supercritical velocities tended to develop over the submerged crest line of this nose as the high velocity core moved from side to side in the outlet channel. It was also observed that the projecting nose was necessary to ensure the smooth confluence of the two flows and to create a similar velocity distribution across the Red River at the downstream control sections.

LIST OF TABLES

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VI	Riprap Sizes for the Upstream Transition
VII	Wing Wall and Approach Channel Results Model "A"
VIII	Riprap Sizes for the Outlet Channel

TABLE I

MODEL "A" CONFIGURATIONS TESTED

Variable	Configurations Tested
Upstream Transition	500 Feet in length. Slopes vary from 6:1 at the start to 2.5:1 at the upstream wing walls.
Upstream Wing Walls	11-Foot, 15-foot, 20-foot, and 25-foot radius raised to elevation 754.
Approach Channel.............	16.5 Feet and 0 feet from the end of the wing walls to the upstream face of the ogee.
Rollway......................	With and without chute blocks.
Stilling Basin Length	150 Feet, 120 feet, 90 feet and 0 feet.
Training Walls	Horizontal crest at elevation 749 for the length of the stilling basin or a minimum of 90 feet.
	Sloped at 2:1 for a base length of 90 feet used with no stilling basin.
Downstream Wing Walls	Horizontal crest at elevation 749 to intersect the dyke slopes.
	Without wing walls.
Outlet Channel Configuration ...	Both banks straight.
	West bank straight, east bank flared at 6:1.
	West bank straight, east bank flared at 6:1 for 300 feet, then an additional 6:1 flare.
	West bank shortened 440 feet, east bank flared at 6:1.
	West bank shortened 440 feet, east bank flared at 6:1 for 300 feet, then an additional 6:1 flare.
	Both banks straight and riprapped.
	Both banks flared at 10:1.

TABLE II

MODEL "B" CONFIGURATIONS TESTED

Variable	Configurations Tested
Upstream Transition	496 feet in length. 6:1 slopes for 385 feet, slopes vary from 6:1 to 2.5:1 for the next 100 feet. The last 11 feet within the wing walls.
	496 feet in length. Slopes vary from 6:1 to 2:1 over the first 485 feet.
	496 feet in length. 6:1 lopes for 385 feet, slopes vary from 6:1 to 2:1 in the next 100 feet.
Upstream Wing Walls	11-foot radius raised to elevation 753.
Approach Channel	16.6 feet from the start of the wing walls to elevation 727 on the sloping ogee face.
Rollway	With and without chute blocks.
Stilling Basin Length	120 feet, 100 feet, 66 feet, 19 feet and 0 feet.
Training Walls	Horizontal crest at elevation 746 for the 120-foot and 100-foot stilling basins.
	Sloped at 2.5:1 from elevation 746 to elevation 716.5 for the 66-foot stilling basin.
	Sloped at 2.5:1 from elevation 746 to elevation 712 for the 19-foot and 0-foot stilling basins.
	Sloped at 2:1 from elevation 755 to elevation 711.5, then horizontal at 711.5 for 10 feet also used without a stilling basin.

Table II - 2

Variable	Configurations Tested
Downstream Wing Walls	Horizontal crest at elevation 723 for the 120-foot and 100-foot stilling basins.
	Horizontal crest at elevation 716.5, elevation 712, and elevation 711.5 for the corresponding training walls.
Outlet Channel Configuration	Both banks straight and riprapped.
	West bank straight and riprapped, east bank flared at 6:1.
	West bank straight and riprapped, east straight and riprapped for 172.5 feet, then a 2-degree 30-minute curve to a 5:1 flare.
	West bank straight and riprapped, east straight and riprapped for 418 feet, then a 2-degree 30-minute curve to a 4:1 flare.
	West bank straight and riprapped, east straight and riprapped for 528 feet, then a 2-degree 30-minute curve to a 3:1 flare.
	Same as above, but the east bank riprapped for 800 feet.
	Same as above, but the east bank riprapped for 1,050 feet.
	Same as above, but both banks riprapped throughout.

TABLE III

DISCHARGE COMBINATIONS USED IN TESTING OF THE OUTLET CONTROL WORKS MODELS

Model "A"

Floodway Discharge (cfs)	Red River Discharge (cfs)	Tailwater Level	Assiniboine River Contribution	Remarks
0	98,000	732.8	Average)	
0	132,000	737.3	Average)	Natural river conditions
0	178,000	743.8	Minimum)	
0	200,000	746.8	Maximum)	
30,000	45,000	729.7	Average	
50,000	48,000	732.7	Average	
60,000	72,000	737.3	Average	Headwater level criteria 752.2
72,000	110,000	744.4	Average	
80,000	94,000	743.2	Average	
100,000	78,000	743.8	Minimum)	
100,000	90,000	745.5	Average)	Headwater level criteria 762.0

Model "B"

Floodway Discharge (cfs)	Red River Discharge (cfs)	Tailwater Level	Assiniboine River Contribution	Remarks
0	132,000	737.3	Average)	Natural river conditions
0	137,000	738.0	Average)	
0	178,000	743.8	Minimum)	
10,000	33,700	724.1	Average	
30,000	37,300	728.4	Average	
50,000	47,700	732.9	Average	
60,000	77,000	738.0	Average	Headwater level criteria 752.2
100,000	90,000	745.5	All contributions	Headwater level criteria 762.0

R E D   R I V E R   F L O O D W A Y

SUMMARY OF TESTS COMPLETED ON THE OUTLET CONTROL WORKS MODEL

MODEL "A"

TABLE IV

TEST NO.	SITUATION TEST NO.	FLOODWAY DISCHARGE	RED RIVER DISCHARGE	TAILWATER LEVEL	UPSTREAM TRANSITION LENGTH AND SLOPES	UPSTREAM WING WALLS	APPROACH CHANNEL	ROLLWAY CREST ELEVATION	CHUTE BLOCKS	STILLING BASIN LENGTH	TRAINING WALL SHAPE	DOWNSTREAM WING WALLS	OUTLET CHANNEL CONFIGURATION	OUTLET CHANNEL BANK PROTECTION	REMARKS
1	A	60,000	82,000	738.7	500' SLOPES VARY FROM 6:1 TO 2.5:1	11' RADIUS ELEV. 754'	16.5', ELEV. 727'	730.0'	YES	150'	HORIZ. CREST AT ELEV. 749'	HORIZ. CREST AT ELEV. 749'	STRAIGHT	NONE	
2	A	100,000	82,000	744.4	"	"	"	"	"	"	"	"	"	"	
3	A	72,000	110,000	744.4	"	"	"	"	"	"	"	"	"	"	EXCESSIVE RIPPLING OF THE BED, MATERIAL "A".
4	A	80,000	82,000	741.5	"	"	"	"	"	"	"	"	"	"	GENERAL ASSESSMENT OF ORIGINAL DESIGN, AND
5	A	60,000	82,000	737.8	"	"	"	"	"	"	"	"	"	"	BED MATERIAL.
6	A	50,000	62,000	734.7	"	"	"	"	"	"	"	"	"	"	
7	A	30,000	45,000	729.7	"	"	"	"	"	"	"	"	"	"	NOT COMPLETED
8	A	50,000	48,000	732.7	"	"	"	"	"	"	"	"	"	"	
9	A	60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
10	A	80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	GENERAL ASSESSMENT OF ORIGINAL DESIGN, AND BED MATERIAL.
11	A	100,000	90,000	745.5	"	"	"	"	"	"	"	"	"	"	MODERATE RIPPLING OF THE BED, MATERIAL "B".
12	A	100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	
13		50,000	48,000	732.8	"	"	"	"	"	"	"	"	"	"	ONLY THE WATER SURFACE PROFILE THROUGH THE STRUCTURE MEASURED. TEST TO ALLOW DECISION OF WING WALL SHAPE AND LENGTH OF APPROACH CHANNEL.
14		72,000	110,000	744.4	"	"	"	"	"	"	"	"	"	"	NOT COMPLETED
15		60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
16		80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
17		100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	
18		50,000	48,000	732.8	"	15' RADIUS ELEV. 754'	"	"	"	"	"	"	"	"	
19		60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
20	A	60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
21		80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
22		100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	
23		50,000	48,000	732.8	"	20' RADIUS ELEV. 754'	"	"	"	"	"	"	"	"	
24		60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	ONLY THE WATER SURFACE PROFILE THROUGH THE STRUCTURE MEASURED.
25		80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	ASSESSMENT OF WING WALL SHAPE AND LENGTH OF APPROACH CHANNEL.
26		100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	
27		50,000	48,000	732.8	"	25' RADIUS ELEV. 754'	"	"	"	"	"	"	"	"	
28		60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
29		80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
30		100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	
31		100,000	78,000	743.8	"	"	0'	"	"	"	"	"	"	"	
32		80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
33		60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	

RED RIVER FLOODWAY
SUMMARY OF TESTS COMPLETED ON THE OUTLET CONTROL WORKS MODEL
MODEL "A"

TABLE IV - SHEET 2

TEST NO.	SITUATION TEST NO.	FLOODWAY DISCHARGE	RED RIVER DISCHARGE	TAILWATER LEVEL	UPSTREAM TRANSITION LENGTH AND SLOPES	UPSTREAM WING WALLS	APPROACH CHANNEL	ROLLWAY CREST ELEVATION	CHUTE BLOCKS	STILLING BASIN LENGTH	TRAINING WALL SHAPE	DOWNSTREAM WING WALLS	OUTLET CHANNEL CONFIGURATION	OUTLET CHANNEL BANK PROTECTION	REMARKS
34		50,000	48,000	732.8	500', VARIABLE SLOPE 6:1 TO 2.5:1	25' RADIUS ELEV. 754'	0'	730.0'	YES	150'	HORIZ. CREST AT ELEV. 749'	HORIZ. CREST AT ELEV. 749'	STRAIGHT	NONE	
35		50,000	48,000	732.8	"	20' RADIUS ELEV. 754'	"	"	"	"	"	"	"	"	
36		60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
37		80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
38		100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	
39		100,000	78,000	743.8	"	15' RADIUS ELEV. 754'	"	"	"	"	"	"	"	"	ONLY THE WATER SURFACE PROFILE THROUGH THE STRUCTURE MEASURED. ASSESSMENT OF WING WALL SHAPE AND LENGTH OF APPROACH CHANNEL.
40		80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
41		60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
42		50,000	48,000	732.8	"	"	"	"	"	"	"	"	"	"	
43		50,000	48,000	732.8	"	11' RADIUS ELEV. 754'	"	"	"	"	"	"	"	"	
44		60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
45		80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
46		100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	
47	B-1	50,000	48,000	732.8	"	"	"	"	"	120'	"	"	"	"	ASSESSMENT OF THE EFFECT OF SHORTENING THE STILLING BASIN ON SCOUR ACTION IN THE OUTLET CHANNEL, MATERIAL "C".
48	B-1	60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
49	B-1	80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
50	B-1	100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	
51	B-2 *	50,000	48,000	732.8	"	"	"	"	"	90'	"	"	"	"	NOT COMPLETED AS STILLING BASIN FOUND TO BE OUT OF LINE WITH THE STRUCTURE CENTRELINE.
52	B-2	50,000	48,000	732.8	"	"	"	"	"	"	"	"	"	"	
53	B-2	100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	TENDENCY FOR THE RED RIVER FLOWS TO DEFLECT THE FLOODWAY FLOWS RESULTS IN EXTENSIVE SCOUR OF THE EAST BANK.
54	B-2	60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
55	B-2	80,000	84,000	743.2	"	"	"	"	"	"	"	"	6:1 FLARE ON EAST BANK WEST STRAIGHT	"	ASSESSMENT OF THE EFFECT OF FLARING THE OUTLET CHANNEL ON THE SCOUR ACTION IN THE OUTLET CHANNEL.
56	C-1	50,000	48,000	732.8	"	"	"	"	"	"	"	"		"	
57	C-1	60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	RETURN EDDY ON THE EAST BANK DEFLECTS THE FLOODWAY FLOWS AND RESULTS IN EXTENSIVE SCOUR OF THE WEST BANK.
58	C-1	80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
59	C-1	100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	
60	C-4	50,000	48,000	732.8	"	"	"	"	"	"	"	"	6:1 FLARE EAST, WEST SHORTENED	"	NO DEFLECTION OF THE RED RIVER FLOWS RESULTS IN EXCESSIVE EROSION OF THE EAST BANK.
61	C-4	60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
62	C-4	80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
63	C-4	100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	

RED RIVER FLOODWAY

SUMMARY OF TESTS COMPLETED ON THE OUTLET CONTROL WORKS MODEL

MODEL "A"

TABLE IV - SHEET 3

TEST NO.	SITUATION TEST NO.	FLOODWAY DISCHARGE	RED RIVER DISCHARGE	TAILWATER LEVEL	UPSTREAM TRANSITION LENGTH AND SLOPES	UPSTREAM WING WALLS	APPROACH CHANNEL	ROLLWAY CREST ELEVATION	CHUTE BLOCKS	STILLING BASIN LENGTH	TRAINING WALL SHAPE	DOWNSTREAM WING WALLS	OUTLET CHANNEL CONFIGURATION	OUTLET CHANNEL BANK PROTECTION	REMARKS
64	C-5	50,000	43,000	732.8	500', VARIABLE SLOPE 6:1 TO 2.5:1	11' RADIUS ELEV. 754'	0'	730.0'	YES	90'	HORIZ. CREST AT ELEV. 749'	HORIZ. CREST AT ELEV. 749'	6:1 & 6:1,EAST WEST ALTERNATE	NONE	NO DEFLECTION OF THE RED RIVER FLOWS RESULTS IN EXCESSIVE EROSION OF THE EAST BANK.
65	C-5	60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
66	C-5	80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
67	C-5	100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	
68	C-2	50,000	43,000	732.8	"	"	"	"	"	"	"	"	6:1 & 6:1, ON EAST BANK	"	RETURN EDDY ON THE EAST BANK DEFLECTS THE FLOODWAY FLOWS AND RESULTS IN EXCESSIVE SCOUR OF THE WEST BANK.
69	C-2	60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
70	C-2	80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
71	C-2	100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	
72	C-3	50,000	48,000	732.8	"	"	"	"	"	"	"	"	EAST STRAIGHT WEST ALTERNATE	"	NO DEFLECTION OF THE RED RIVER FLOWS RESULTS IN EXCESSIVE EROSION OF THE EAST BANK.
73	C-3	60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	
74	C-3	80,000	94,000	743.2	"	"	"	"	"	"	"	"	"	"	
75	C-3	100,000	78,000	743.3	"	"	"	"	"	"	"	"	"	"	
76	C-1 *	60,000	72,000	737.3	"	"	"	"	"	"	"	REMOVED	6:1 EAST, WEST STRAIGHT	"	TO ASSESS THE EFFECT OF REMOVING THE DOWNSTREAM WING WALLS. FOUND EROSION IN THE STILLING BASIN AREA WAS NOT NOTICEABLY INCREASED.
77	C-1 *	100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	HIGHER FLOODWAY FLOW RESULTS IN EXTENSIVE EROSION OF THE EAST BANK.
78	D-1	60,000	72,000	737.3	"	"	"	"	"	"	"	"	EAST AND WEST FLARED AT 10:1	"	SLIGHT EROSION OF THE TIP OF THE WEST BANK.
79	D-1	100,000	78,000	743.8	"	"	"	"	"	"	"	"	"	"	EXTENSIVE ATTACK OF THE EAST BANK.
80	B-2 *	100,000	78,000	743.8	"	"	"	"	"	"	"	"	BOTH STRAIGHT	BOTH BANKS RIPRAPPED	NO EROSION
81	B-2 *	60,000	72,000	737.3	"	"	"	"	"	"	"	"	"	"	NO EROSION
82	D-2	60,000	72,000	737.3	"	"	"	"	"	0'	SLOPED AT 2:1	"	BOTH FLARED AT 10:1	NONE	SLIGHT EROSION OF THE TIP OF THE WEST BANK. ASSESSMENT OF THE EFFECT ON DOWNSTREAM SCOUR OF SLOPING THE TRAINING WALLS.
83	D-2	30,000	36,000	742.1	"	"	"	"	NO	"	"	"	"	"	EXTENSIVE EROSION OF THE EAST BANK.
84	D-2	100,000	77,000	743.8	"	"	"	"	"	"	"	"	"	"	EXCESSIVE EROSION OF THE EAST BANK.
85	D-2 *	100,000	77,000	743.8	"	"	"	"	"	"	HORIZ. CREST AT ELEV. 749'	"	"	"	EXCESSIVE EROSION OF THE EAST BANK.
86	D-2 *	60,000	72,000	737.3	"	"	"	"	"	"		"	"	"	EXTENSIVE EROSION OF THE EAST BANK.
87		0	178,000	743.8	FLOODWAY CLOSED OFF										NO EROSION. NATURAL RIVER CONDITIONS. DEVELOPMENT OF VELOCITY DISTRIBUTION CRITERIA BELOW THE CONFLUENCE.
88		0	132,000	737.3											
89		0	98,000	732.8											
90		0	200,000	746.8											

RED RIVER FLOODWAY

SUMMARY OF TESTS COMPLETED ON THE OUTLET CONTROL WORKS MODEL

MODEL "B"

TABLE IV - SHEET 4

TEST NO.	SITUATION TEST NO.	FLOODWAY DISCHARGE	RED RIVER DISCHARGE	TAILWATER LEVEL	UPSTREAM TRANSITION LENGTH AND SLOPES	UPSTREAM WING WALLS	APPROACH CHANNEL	ROLLWAY CREST ELEVATION	CHUTE BLOCKS	STILLING BASIN LENGTH	TRAINING WALL SHAPE	DOWNSTREAM WING WALLS	OUTLET CHANNEL CONFIGURATION	OUTLET CHANNEL BANK PROTECTION	REMARKS
1	1	0	132,000	737.3	FLOODWAY CLOSED OFF										NO EROSION. NATURAL RIVER CONDITIONS. DEVELOPMENT OF VELOCITY DISTRIBUTION CRITERIA BELOW THE CONFLUENCE.
2	2	0	178,000	743.8	"										
3	3	60,000	72,400	737.3	496', 385' SLOPES AT 6:1, LAST 100' VARIABLE SLOPE 6:1 TO 2.5:1	11' RADIUS ELEV. 753'	16.6'	730.0'	YES	120', ELEV.707.5'	HORIZ. CREST AT ELEV. 746'	HORIZ. CREST AT ELEV. 723'	STRAIGHT	BOTH BANKS RIPRAPPED	NO EROSION. UPSTREAM WATER LEVELS EXCEED CRITERIA BY 0.6 FT. VELOCITY DISTRIBUTION IN RIVER DISTORTED FROM NATURAL CONDITIONS.
4	4(b)	60,000	72,400	737.3	"	"	"	"	"	"	"	"	EAST AT 6:1, WEST STRAIGHT	WEST RIPRAPPED	NO EROSION
5	4(c)	60,000	72,400	737.3	"	"	"	"	NO	"	"	"	"	"	NO EROSION
6	5	60,000	72,400	737.3	"	"	"	"	"	100', ELEV.707.5'	"	"	"	"	NO EROSION
7	6	60,000	72,400	737.3	"	"	"	"	"	66', ELEV.707.5'	SLOPED AT 2.5:1	HORIZ. CREST AT ELEV. 716.5'	"	"	NO EROSION
8	16	60,000	77,000	738.0	"	"	"	"	"	"	"	"	"	"	NO EROSION
9	7	60,000	77,000	738.0	"	"	"	"	"	19', ELEV.707.5'	"	HORIZ. CREST AT ELEV. 712'	"	"	NO EROSION. END SILL FORMS A SIMPLE FLIP BUCKET.
10	8	60,000	77,000	738.0	"	"	"	"	"	0', ELEV.707.5'	"	"	"	"	NO EROSION
11	17	0	137,000	738.0	FLOODWAY CLOSED OFF										NATURAL RIVER CONDITIONS.
12	18	60,000	77,000	738.0	496', 385' SLOPES AT 6:1, LAST 100' VARIABLE SLOPE 6:1 TO 2.5:1	11' RADIUS ELEV. 753'	"	MODIFIED 730.0'	"	"	"	"	"	"	NO EROSION. UPSTREAM WATER LEVELS NOW MEET CRITERIA OF 752.2.
13	9	10,000	33,700	724.1	"	"	"	"	"	"	"	"	"	"	CALIBRATION OF THE STRUCTURE.
14	10	30,000	39,300	728.4	"	"	"	"	"	"	"	"	"	"	
15	11	50,000	47,700	732.9	"	"	"	"	"	"	"	"	"	"	
16	15	100,000	90,000	745.5	"	"	"	"	"	"	"	"	"	"	
17	13	60,000	77,000	738.0	"	"	"	"	"	0', ELEV.710.5'	"	"	"	"	SIMILAR RESULTS AS FOR THE OGEE ENDING AT ELEVATION 707.5.
18	14	60,000	77,000	738.0	"	"	"	"	"	0', ELEV.707.5'	"	"	BOTH STRAIGHT	BOTH RIPRAPPED	DISTORTION OF RIVER VELOCITY DISTRIBUTION FROM NATURAL CONDITIONS.
19	19	60,000	77,000	738.0	"	"	"	"	"	"	"	"	WEST STRAIGHT, EAST STRAIGHT FOR 172.5' THEN 5:1 FLARE.	WEST RIPRAPPED	NO EROSION
20	20	60,000	77,000	738.0	"	"	"	"	"	"	"	"	WEST STRAIGHT, EAST STRAIGHT FOR 418' THEN 4:1 FLARE.	WEST RIPRAPPED, EAST FOR 418'	EXTENSIVE EROSION OF EAST BANK PAST RIPRAP SECTION.

RED RIVER FLOODWAY

SUMMARY OF TESTS COMPLETED ON THE OUTLET CONTROL WORKS MODEL

MODEL "B"

TABLE IV - SHEET 5

TEST NO.	SITUATION TEST NO.	FLOODWAY DISCHARGE	RED RIVER DISCHARGE	TAILWATER LEVEL	UPSTREAM TRANSITION LENGTH AND SLOPES	UPSTREAM WING WALLS	APPROACH CHANNEL	ROLLWAY CREST ELEVATION	CHUTE BLOCKS	STILLING BASIN LENGTH	TRAINING WALL SHAPE	DOWNSTREAM WING WALLS	OUTLET CHANNEL CONFIGURATION	OUTLET CHANNEL BANK PROTECTION	REMARKS
21	21	60,000	77,000	738.0	496', 385', SLOPES AT 6:1, LAST 100' VARIABLE SLOPE 6:1 TO 2.5:1.	11' RADIUS ELEV. 753'	16.6'	MODIFIED 730.0'	NO	0', ELEV. 707.5'	SLOPED AT 2.5:1	HORIZ. CREST AT ELEV. 712'	WEST STRAIGHT, EAST STRAIGHT FOR 528' THEN 3:1 FLARE.	WEST RIPRAPPED, EAST FOR 528'	EXTENSIVE EROSION OF EAST BANK PAST RIPRAPPED SECTION.
22	21-A	60,000	77,000	738.0	"	"	"	"	"	"	"	"	"	WEST RIPRAPPED, EAST FOR 800'	SLIGHT EROSION OF EAST BANK PAST RIPRAPPED SECTION UP TO ELEVATION 710.
23	21-B	60,000	77,000	738.0	"	"	"	"	"	"	"	"	"	WEST THROUGHOUT EAST FOR 1050'	SLIGHT EROSION OF EAST BANK PAST RIPRAPPED SECTION TO BELOW THE CONFLUENCE WITH THE RED RIVER UP TO ELEVATION 710.
24	22	60,000	77,000	738.0	"	"	"	"	"	"	"	"	"	BOTH RIPRAPPED	
25	23	60,000	77,000	738.0	496', VARIABLE SLOPE 6:1 TO 2:1	"	"	"	"	"	"	"	"	BOTH RIPRAPPED	UPSTREAM WATER LEVEL 0.4 FEET BELOW CRITERIA.
26	24	60,000	77,000	738.0	"	"	"	"	"	"	SLOPED AT 2:1 TO ELEV.711.5'	HORIZ. CREST AT ELEV. 711.5'	"	"	STRONG RETURN CURRENTS DISTORT DOWNSTREAM VELOCITY DISTRIBUTION.
27	25	100,000	78,000	743.8	"	"	"	"	"	"	THEN HORIZ. TO GIVE TOTAL OF 50' FROM END OF OGEE.	"	"	"	
28	26	60,000	77,000	738.0	496', 335' SLOPES AT 6:1. LAST 100' VARIABLE SLOPE 6:1 TO 2:1.	"	"	"	"	"	SLOPED AT 2.5:1 TO ELEV.712'.	"	"	"	UPSTREAM WATER LEVEL 752.2'.

TABLE V

VARIATION IN HEADWATER LEVELS FOR VARIOUS BANK SLOPES OF THE UPSTREAM TRANSITION

Transition Bank Slopes	Floodway Discharge Cfs	Headwater Level
Slopes vary from 6:1 to 2.5:1 for 500 feet	60,000	752.3 feet Model "A"
6:1 slopes for 385 feet, then slopes vary from 6:1 to 2.5:1 over the next 100 feet	60,000	752.4 feet Model "B"
Slopes vary from 6:1 to 2:1 for 485 feet	60,000	751.9 feet Model "B"
6:1 slopes for 385 feet, then slopes vary from 6:1 to 2:1 over the next 100 feet	60,000	752.2 feet Model "B"

TABLE VI

RIPRAP SIZES FOR THE UPSTREAM TRANSITION

Riprap Size	Location
24-inch cubes	From the start of the wing walls to the rollway face.
16-inch cubes	0 feet to 70 feet upstream from the wing walls on all surfaces up to elevation 753.
8-inch cubes	70 feet to 200 feet upstream from the wing walls on all surfaces up to elevation 753.
4-inch cubes	200 feet to 400 feet upstream from the wing walls on all surfaces up to elevation 753.

TABLE VII

WING WALL AND APPROACH CHANNEL RESULTS - MODEL "A"

Wing Wall Radius (ft)	Approach Channel (ft)	Floodway Discharge (cfs)	Red River Discharge (cfs)	Headwater Level at the Start of the Transition	
				Measured	Criteria
11.0	16.5	60,000	72,000	752.3	752.2
15.0	16.5			752.4	
20.0	16.5			752.3	
25.0	16.5			752.3	
11.0	0			752.8	
15.0	0			752.6	
20.0	0			752.6	
25.0	0			752.2	
11.0	16.5	100,000	78,000	762.0	762.0
15.0	16.5			762.4	
20.0	16.5			762.5	
25.0	16.5			762.5	
11.0	0			762.0	
15.0	0			762.5	
20.0	0			762.8	
25.0	0			762.3	

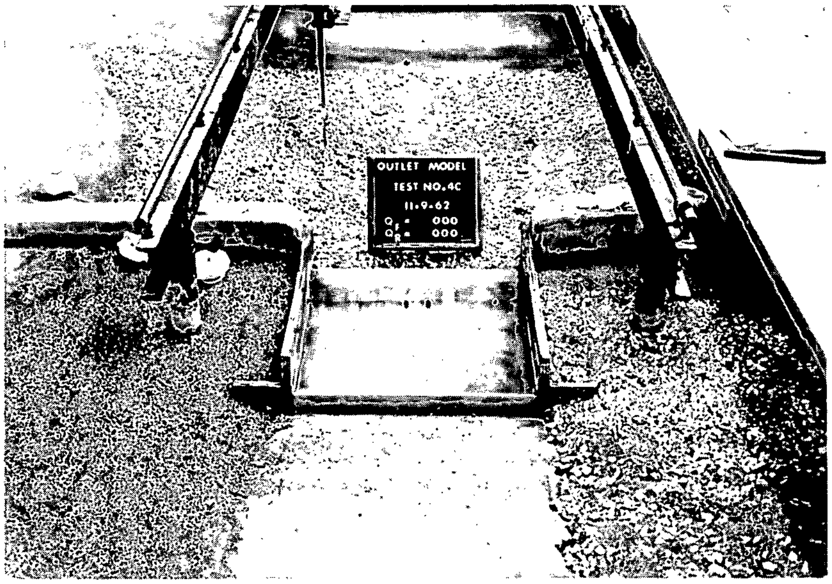
TABLE VIII

RIPRAP SIZES FOR THE OUTLET CHANNEL

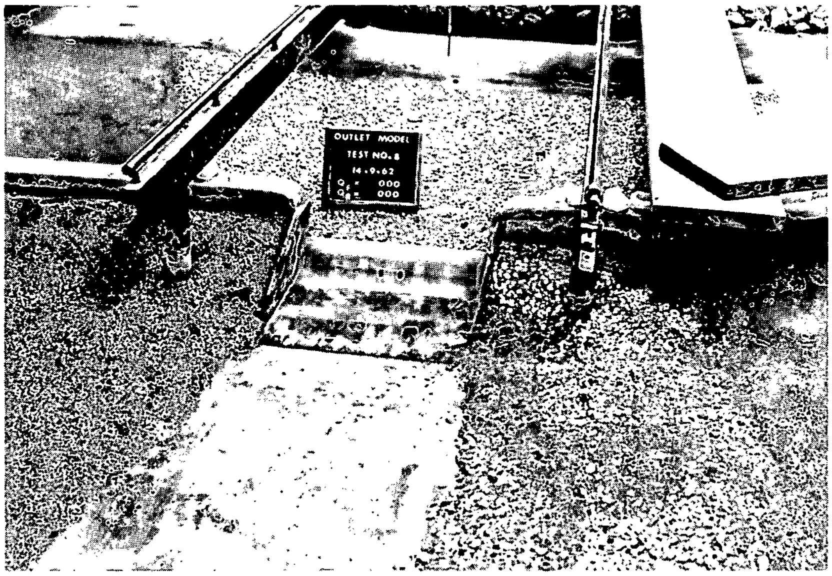
Riprap Size	Distance From End of Rollway	
	West Bank	East Bank
24-inch cubes	0 feet to 150 feet up to elevation 738.	0 feet to 150 feet up to elevation 738.
16-inch cubes	150 feet through to the Red River up to elevation 738 and overtopping the projecting nose on the river slope above elevation 710.	150 feet to 600 feet up to elevation 720.
8-inch cubes		150 feet to 600 feet from elevation 720 to elevation 738. 600 feet to 1,100 feet up to elevation 720.
4-inch cubes		600 feet to 1,100 feet from elevation 720 to elevation 738.

LIST OF PHOTOGRAPHS

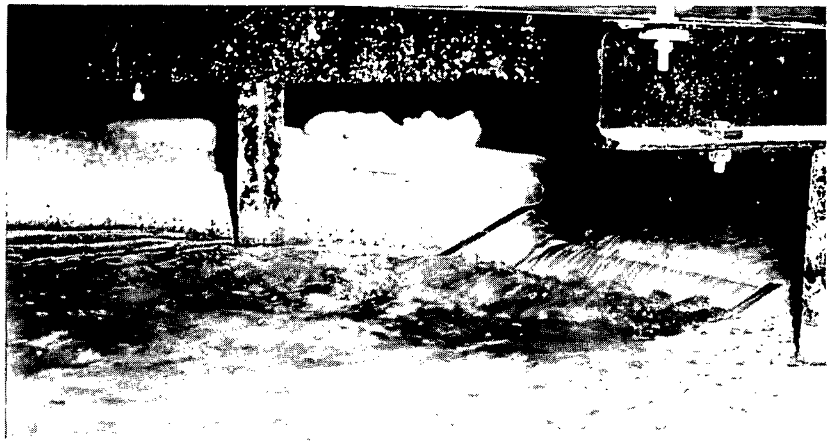
Number	Title
1	Initial Configuration of the Structure for Model "B" Showing the 120-Foot Stilling Basin
2	Final Configuration of the Structure for Model "B" Showing the Sloped Training Walls and No End Sill
3	Downstream Surface Waves With a 19-Foot Stilling Basin Floodway Discharge - 60,000 cfs
4	Downstream Surface Waves Without an End Sill Floodway Discharge - 60,000 cfs
5	Final Channel Configuration Looking Upstream
6	Final Channel Configuration Looking Downstream



PHOTOGRAPH No. 1 — INITIAL CONFIGURATION OF THE STRUCTURE FOR MODEL "B" SHOWING THE 120 FOOT STILLING BASIN.

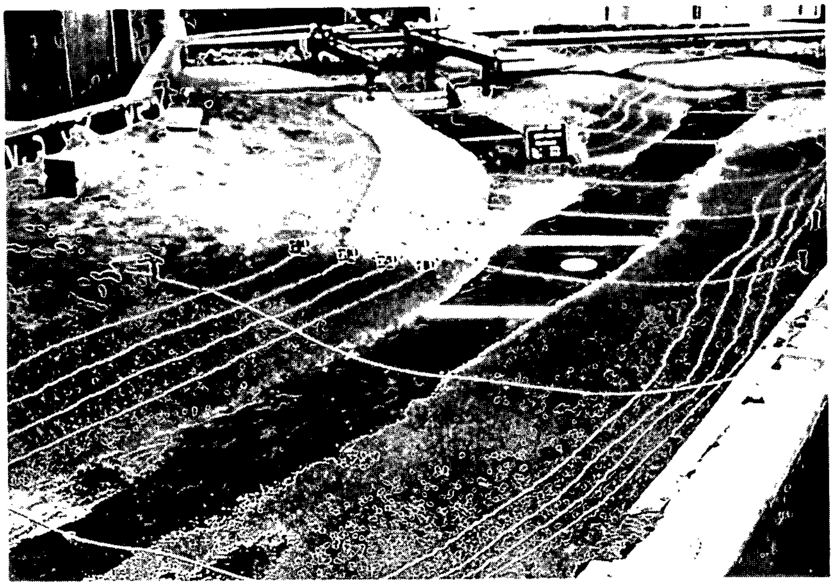


PHOTOGRAPH No. 2 — FINAL CONFIGURATION OF THE STRUCTURE FOR MODEL "B" SHOWING THE SLOPED TRAINING WALLS AND NO END SILL.

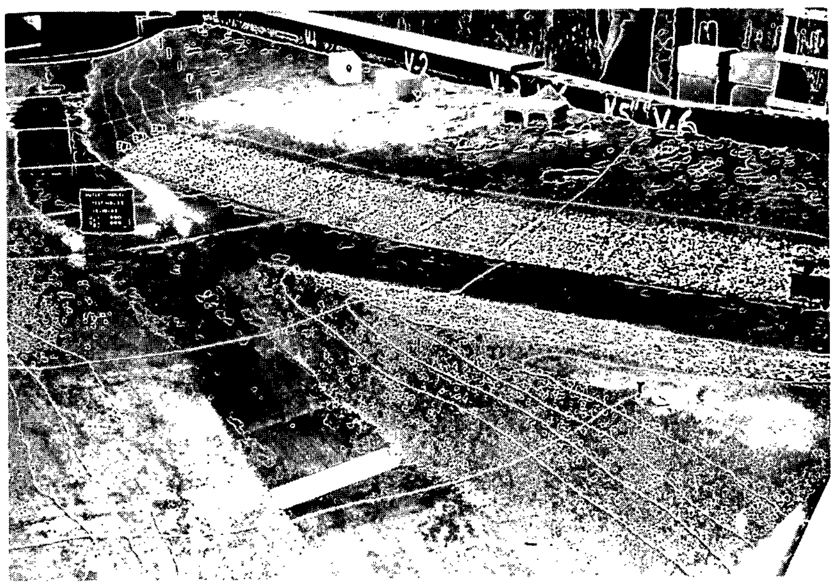


PHOTOGRAPH No. 3 — DOWNSTREAM SURFACE WITH A 19 FOOT STILLING BASIN. FLOODWAY DISCHARGE - 60,000 C.F.S.

PHOTOGRAPH No. 4 — DOWNSTREAM SURFACE WAVES WITHOUT AN END SILL. FLOODWAY DISCHARGE - 60,000 C.F.S.



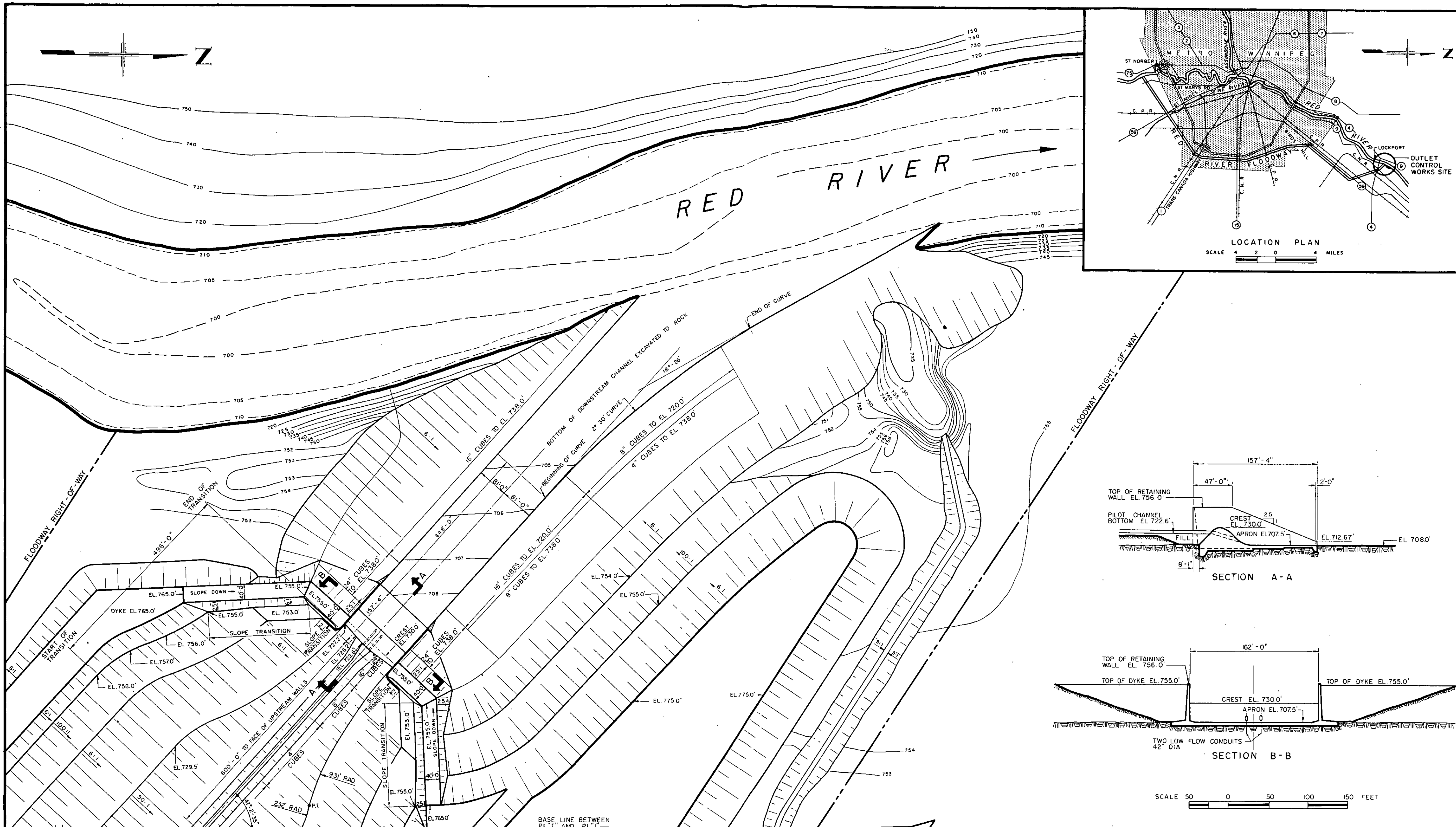
PHOTOGRAPH No. 5 — FINAL CHANNEL CONFIGURATION LOOKING UPSTREAM.



PHOTOGRAPH No. 6 — FINAL CHANNEL CONFIGURATION LOOKING DOWNSTREAM.

LIST OF PLATES

Number	Title
1	Proposed Final Arrangement Plan and Sections
2	General Arrangement - Model "A"
3	Moveable Bed Materials, Grading Curves
4	Rollway Sections - Models "A" and "B"
5	Discharge Rating Curve - Model "B" Modified
6	Water Surface Profiles - Model "A" Floodway Discharge - 60,000 cfs
7	Water Surface Profiles - Model "B" Floodway Discharge - 60,000 cfs
8	Red River Velocity Distributions Discharge - 137,000 cfs, Model "B" Modified



H.G. ACRES & COMPANY LIMITED CONSULTING ENGINEERS

PROVINCE OF MANITOBA
DEPARTMENT OF AGRICULTURE AND CONSERVATION
WATER CONTROL AND CONSERVATION BRANCH

RED RIVER FLOODWAY
OUTLET CONTROL WORKS

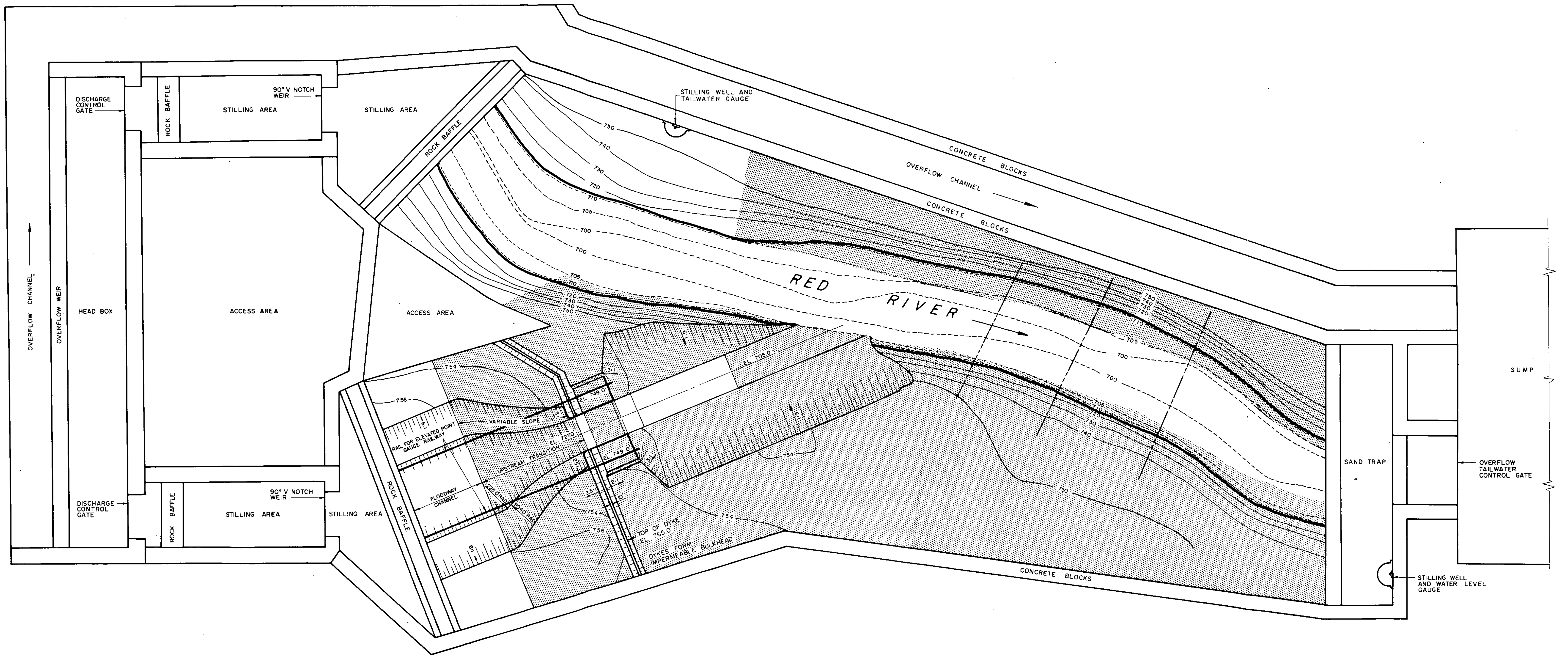
PROPOSED FINAL ARRANGEMENT PLAN AND SECTIONS

H.G. ACRES & COMPANY LIMITED

DATE DECEMBER 1962

PLATE I

SK-940-A-121



LEGEND

DENOTES MOVEABLE BED SECTIONS ALL OTHER AREAS ARE FIXED

SECTIONS USED TO DEVELOP VELOCITY DISTRIBUTIONS.

SCALE 200 0 200 400 600 FEET

H.G. ACRES & COMPANY LIMITED CONSULTING ENGINEERS

PROVINCE OF MANITOBA
DEPARTMENT OF AGRICULTURE AND CONSERVATION
WATER CONTROL AND CONSERVATION BRANCH

RED RIVER FLOODWAY
OUTLET CONTROL WORKS

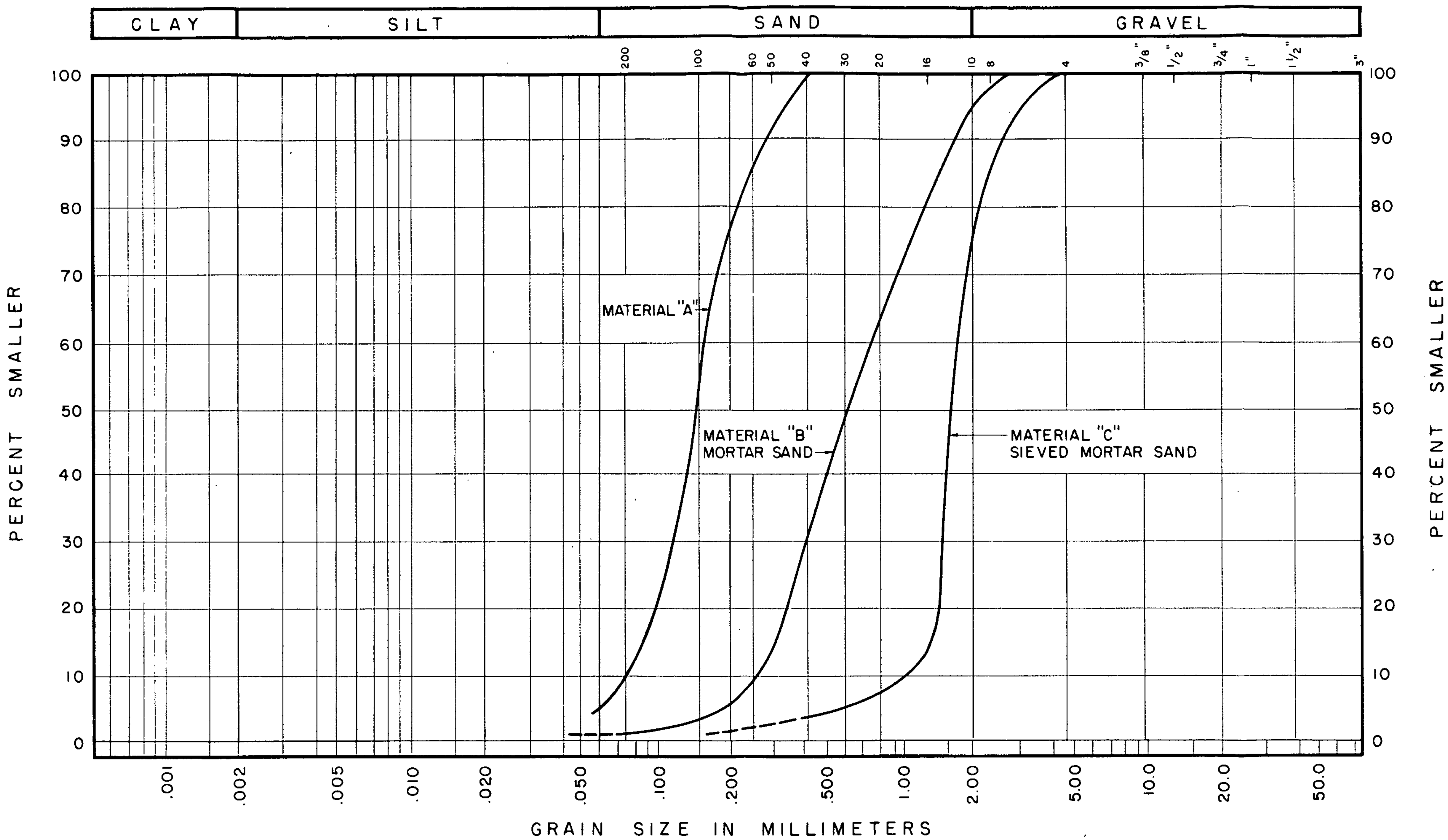
GENERAL ARRANGEMENT
MODEL A

H.G. ACRES & COMPANY LIMITED

DATE DECEMBER 1962

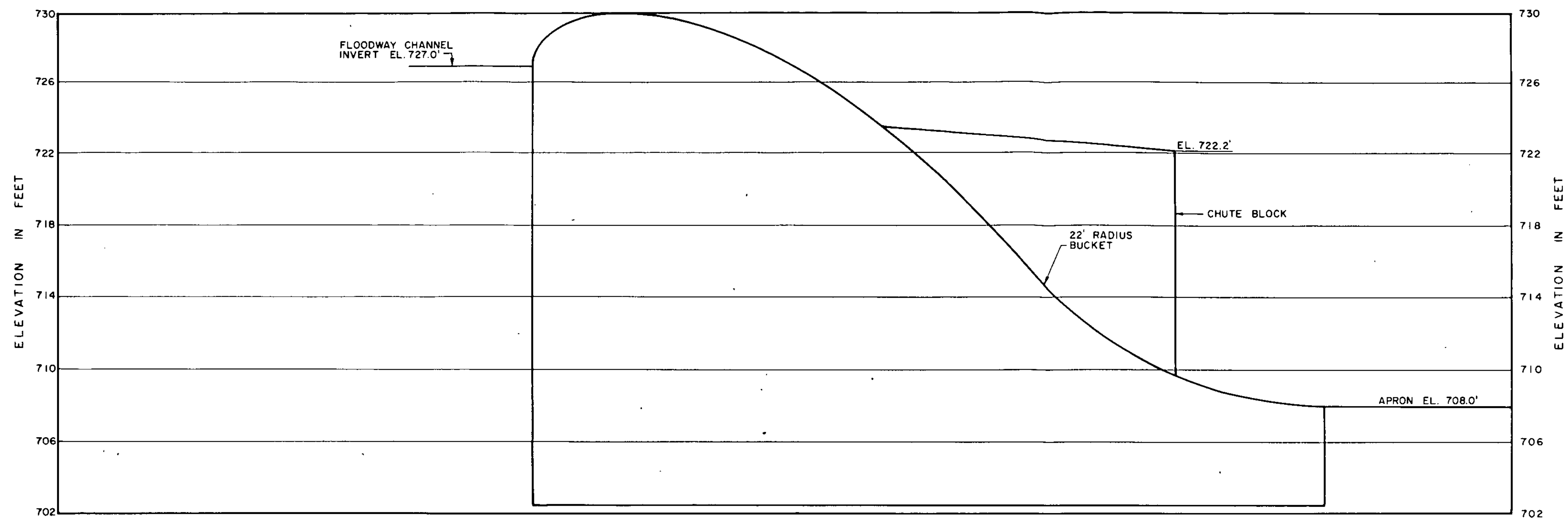
PLATE 2

SK - 940 - SA - 122

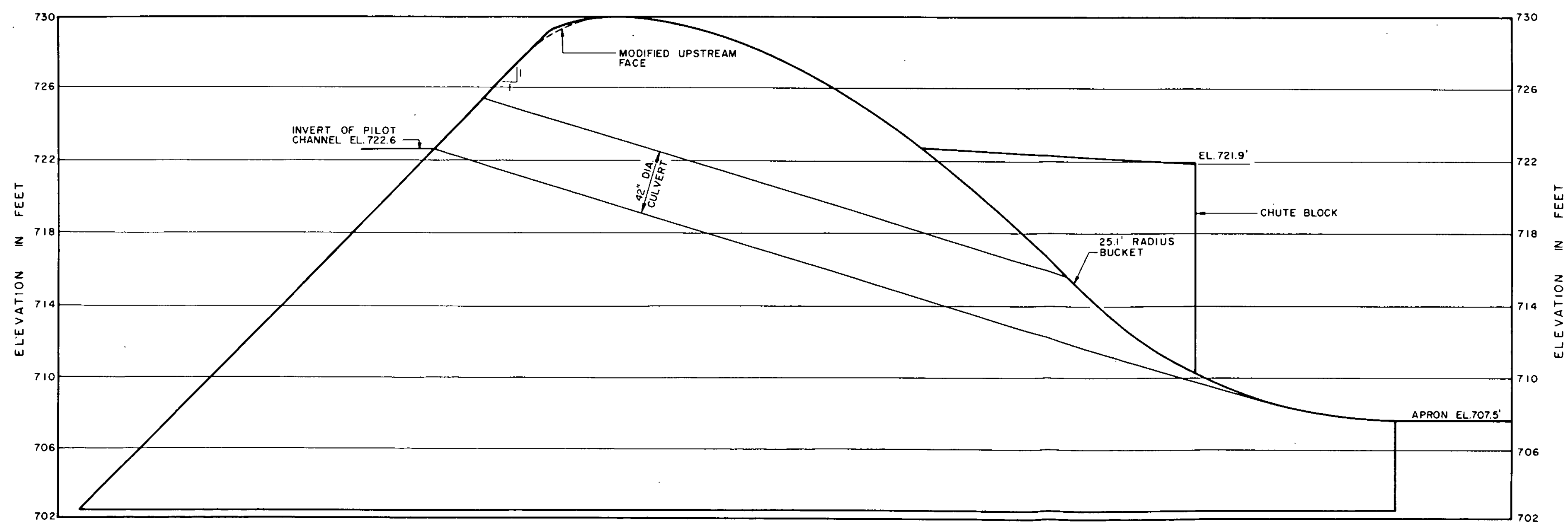


H.G. ACRES & COMPANY LIMITED CONSULTING ENGINEERS
PROVINCE OF MANITOBA DEPARTMENT OF AGRICULTURE AND CONSERVATION WATER CONTROL AND CONSERVATION BRANCH
RED RIVER FLOODWAY OUTLET CONTROL WORKS
MOVEABLE - BED MATERIALS GRADING CURVES
H.G. ACRES & COMPANY LIMITED — DATE DECEMBER 1962 — PLATE 3

SK-940-A-123



MODEL A



MODEL B

SCALE 4 0 4 8 12 FEET

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PROVINCE OF MANITOBA
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WATER CONTROL AND CONSERVATION BRANCH

RED RIVER FLOODWAY
OUTLET CONTROL WORKS

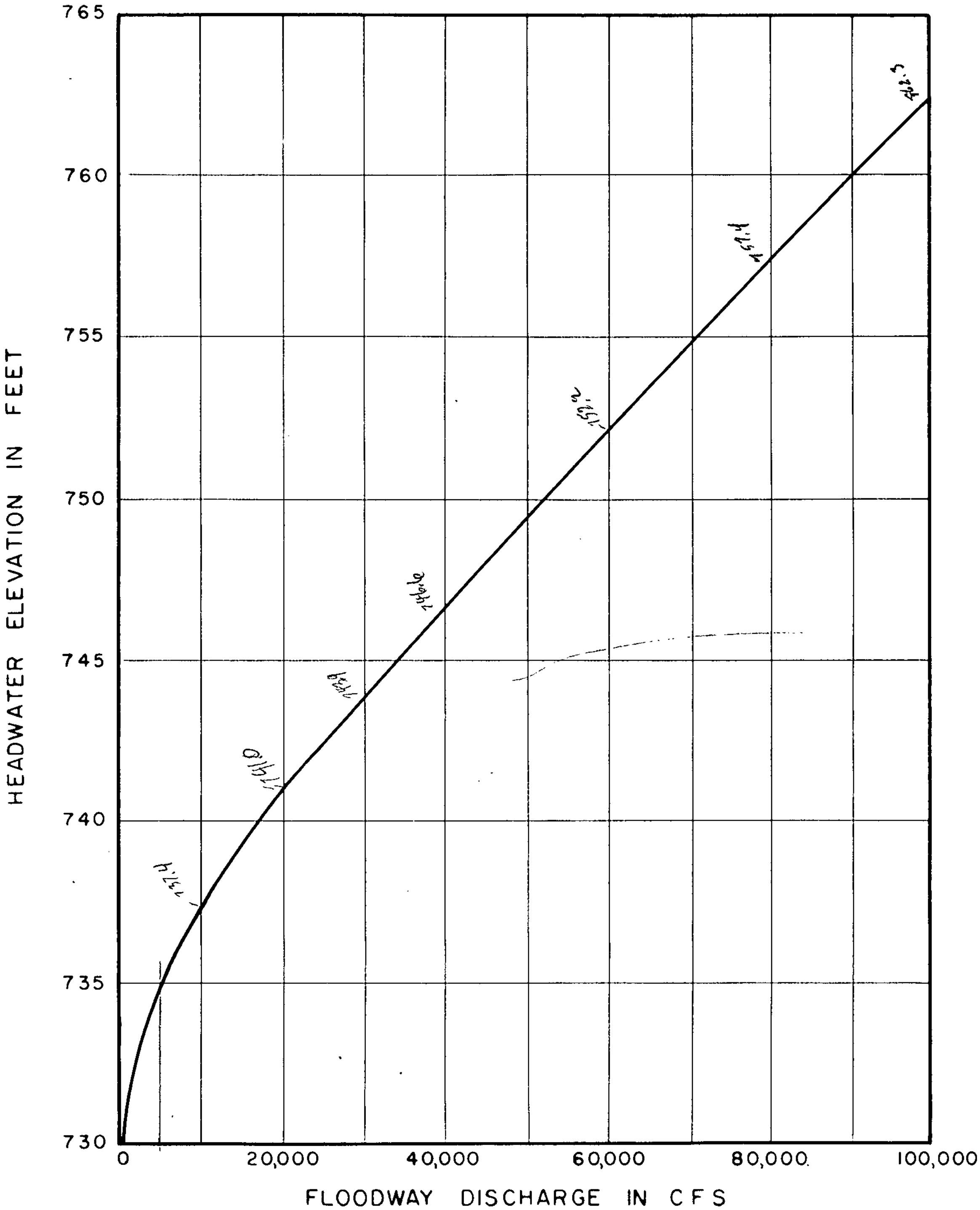
ROLLWAY SECTIONS
FOR MODELS A AND B

H. G. ACRES & COMPANY LIMITED

DATE DECEMBER 1962

PLATE 4

SK-940-A-124



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PROVINCE OF MANITOBA
DEPARTMENT OF AGRICULTURE AND CONSERVATION
WATER CONTROL AND CONSERVATION BRANCH

RED RIVER FLOODWAY
OUTLET CONTROL WORKS

DISCHARGE RATING CURVE

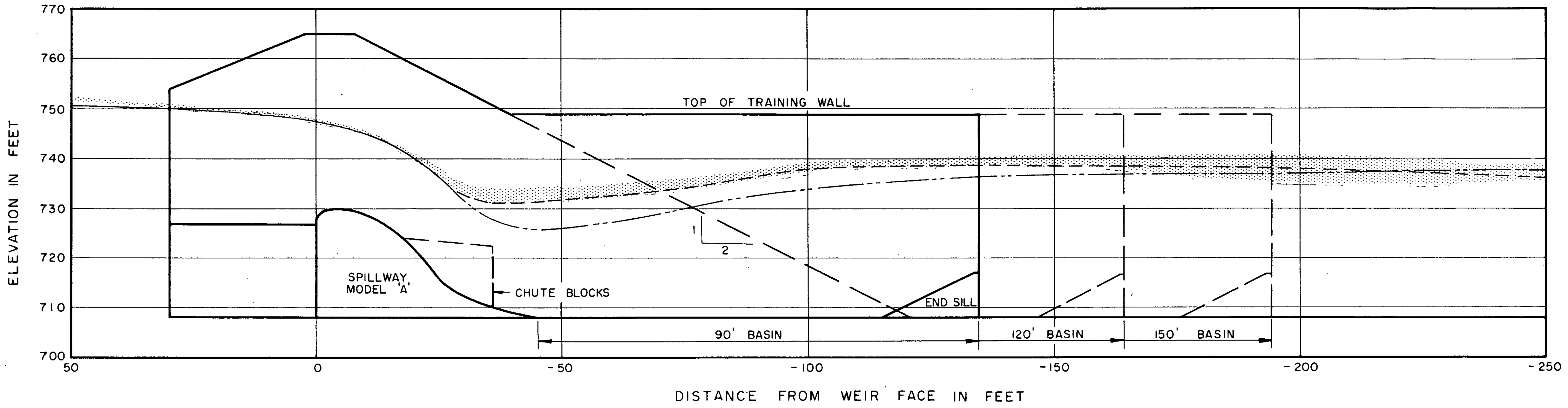
MODEL B MODIFIED

H.G ACRES & COMPANY LIMITED

DATE DECEMBER 1962

PLATE 5

SK-940-LS-125



LEGEND

SYMBOL	TEST No.	ROLLWAY	BASIN LENGTH	TRAINING WALL CREST	CHANNEL CONFIGURATION
ALL PROFILES WITHIN SHADED BAND	44	CHUTE BLOCKS	150	HORIZONTAL AT EL. 749'	STRAIGHT
	48	CHUTE BLOCKS	120	HORIZONTAL AT EL. 749'	STRAIGHT
	76	CHUTE BLOCKS	90	HORIZONTAL AT EL. 749'	WEST STRAIGHT EAST FLARED AT 6 : 1
	78	CHUTE BLOCKS	90	HORIZONTAL AT EL. 749'	BOTH BANKS FLARED AT 10 : 1
	81	CHUTE BLOCKS	90	HORIZONTAL AT EL. 749'	STRAIGHT AND RIPRAPPED
— — —	82	NO BLOCKS	0	SLOPED AT 2 : 1	BOTH BANKS FLARED AT 10 : 1
— - - —	86	NO BLOCKS	0	HORIZONTAL AT EL. 749' FOR 90 FEET	BOTH BANKS FLARED AT 10 : 1

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PROVINCE OF MANITOBA
DEPARTMENT OF AGRICULTURE AND CONSERVATION
WATER CONTROL AND CONSERVATION BRANCH

RED RIVER FLOODWAY
OUTLET CONTROL WORKS

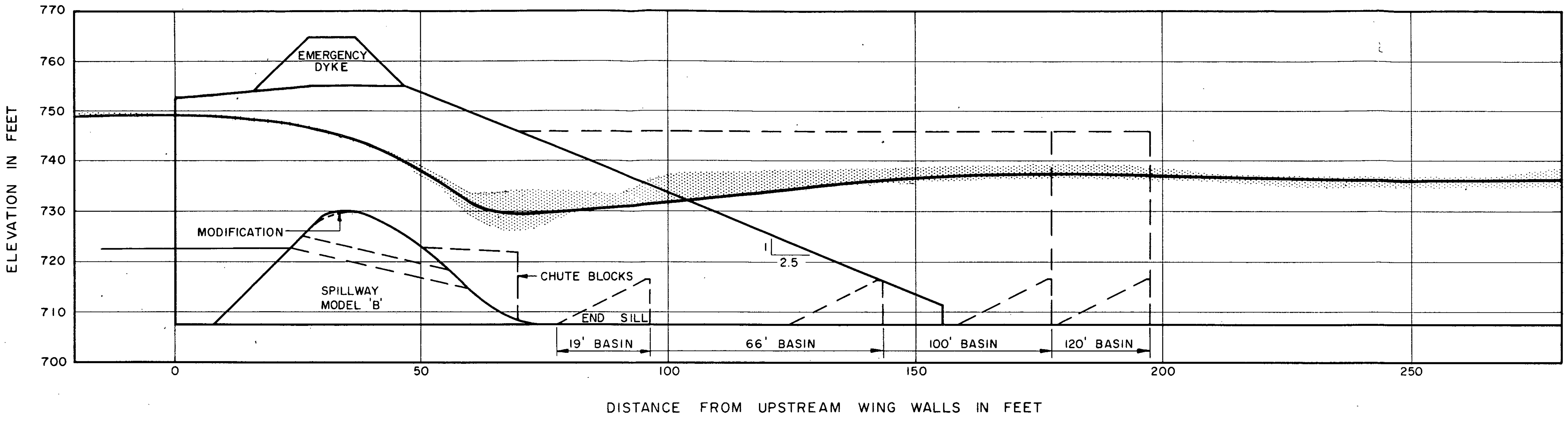
WATER SURFACE PROFILES - MODEL A
FLOODWAY DISCHARGE - 60,000 CFS

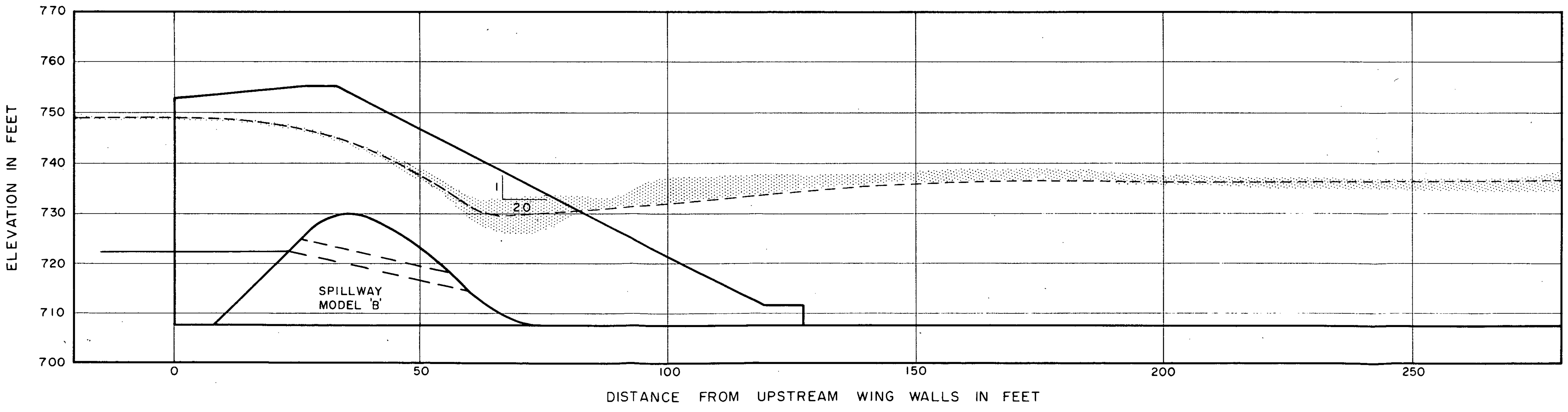
H.G. ACRES & COMPANY LIMITED

DATE DECEMBER 1962

PLATE 6

SK-940 - SA - 126





LEGEND

SYMBOL	TEST No.	ROLLWAY	BASIN LENGTH	TRAINING WALL CREST	CHANNEL CONFIGURATION
ALL PROFILES WITHIN SHADED BAND	3	CHUTE BLOCKS	120	HORIZONTAL AT EL. 746'	STRAIGHT AND RIPRAPPED
	4	CHUTE BLOCKS	120	HORIZONTAL AT EL. 746'	EAST AT 6:1, WEST STRAIGHT AND RIPRAPPED
	5	NO BLOCKS	120	HORIZONTAL AT EL. 746'	EAST AT 6:1, WEST STRAIGHT AND RIPRAPPED
	6	NO BLOCKS	100	HORIZONTAL AT EL. 746'	EAST AT 6:1, WEST STRAIGHT AND RIPRAPPED
	7	NO BLOCKS	66	SLOPED AT 2.5 : 1	EAST AT 6:1, WEST STRAIGHT AND RIPRAPPED
	9	NO BLOCKS	19	SLOPED AT 2.5 : 1	EAST AT 6:1, WEST STRAIGHT AND RIPRAPPED
	10	NO BLOCKS	0	SLOPED AT 2.5 : 1	EAST AT 6:1, WEST STRAIGHT AND RIPRAPPED
— — —	26	NO BLOCKS MODIFIED OGEE	0	SLOPED AT 2:1 AND REDUCED 14 FEET	WEST STRAIGHT, EAST STRAIGHT FOR 528' THEN 3:1 FLARE. BOTH RIPRAPPED
———	28	NO BLOCKS MODIFIED OGEE	0	SLOPED AT 2.5 : 1	WEST STRAIGHT, EAST STRAIGHT FOR 528' THEN 3:1 FLARE. BOTH RIPRAPPED (FINAL CONFIGURATION)

H.G. ACRES & COMPANY LIMITED CONSULTING ENGINEERS

PROVINCE OF MANITOBA
DEPARTMENT OF AGRICULTURE AND CONSERVATION
WATER CONTROL AND CONSERVATION BRANCH

RED RIVER FLOODWAY
OUTLET CONTROL WORKS

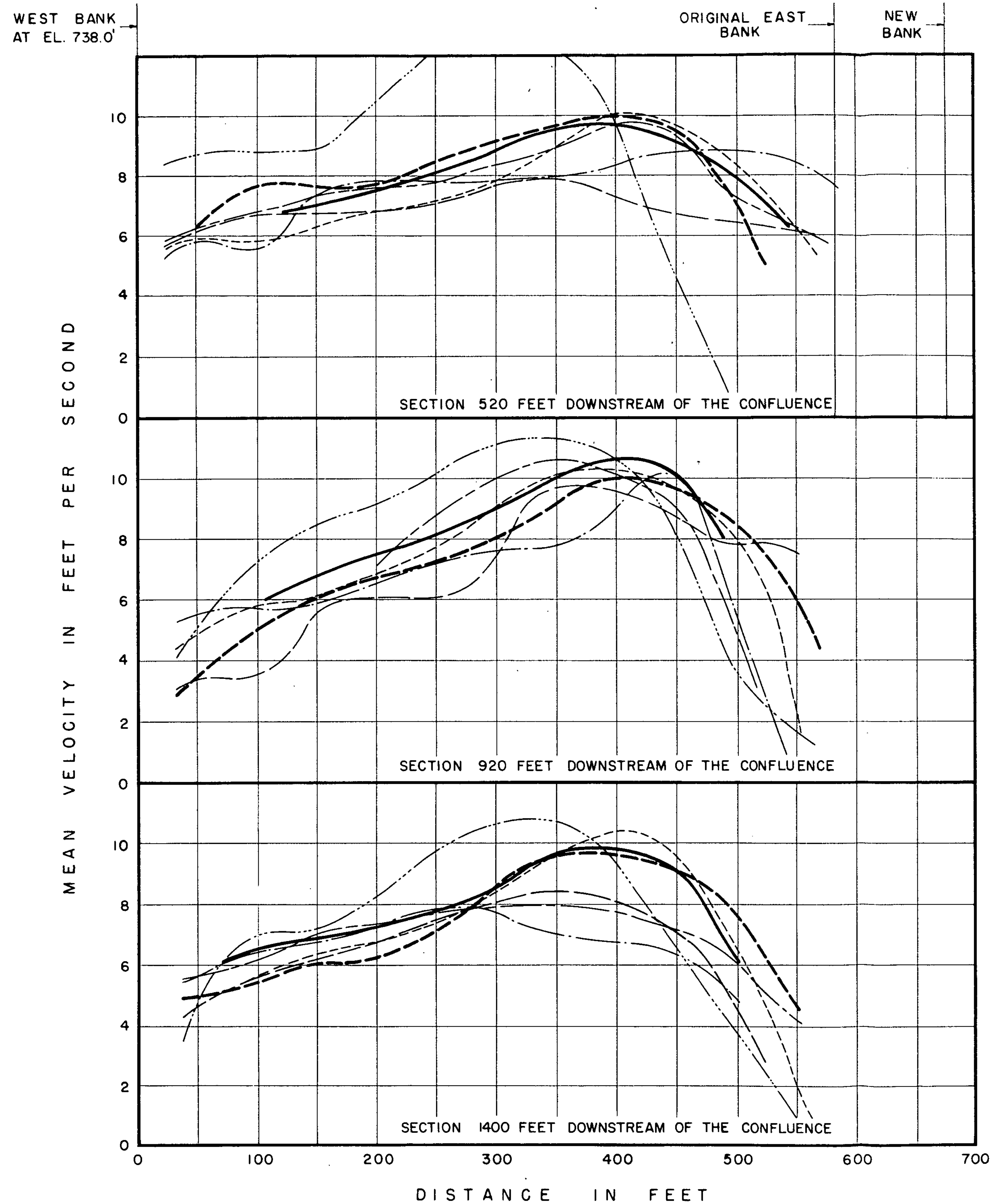
WATER SURFACE PROFILES - MODEL B
FLOODWAY DISCHARGE - 60,000 CFS

H.G. ACRES & COMPANY LIMITED

DATE DECEMBER 1962

PLATE 7

SK - 940 - SA - 127



LEGEND

SYMBOL	TEST NUMBER	STRUCTURE ARRANGEMENT	CHANNEL CONFIGURATION
▬ ▬ ▬	11	NATURAL RIVER CONDITIONS	
- - - - - -	10	NO STILLING BASIN. CREST OF TRAINING WALLS AT EL. 749'	WEST BANK STRAIGHT AND RIPRAPPED. EAST BANK 6:1 FLARE, NO RIPRAP
- - - - -	12	NO STILLING BASIN. TRAINING WALLS SLOPED AT 2.5 : 1	WEST BANK STRAIGHT AND RIPRAPPED. EAST BANK 6:1 FLARE, NO RIPRAP
— ··· —	18	SLOPED AT 2.5 : 1	BOTH BANKS STRAIGHT AND RIPRAPPED
—— ——	19	SLOPED AT 2.5 : 1	WEST BANK STRAIGHT AND RIPRAPPED. EAST BANK STRAIGHT AND RIPRAPPED FOR 172.5 FEET, THEN A 2° 30' CURVE TO A 5:1 FLARE
— · —	20	SLOPED AT 2.5 : 1	WEST BANK STRAIGHT AND RIPRAPPED. EAST BANK STRAIGHT AND RIPRAPPED FOR 418 FEET, THEN A 2° 30' CURVE TO A 4:1 FLARE
— — —	26	NO STILLING BASIN. TRAINING WALL CREST LENGTH REDUCED 14 FEET AND SLOPED AT 2:1	WEST BANK STRAIGHT AND RIPRAPPED. EAST BANK STRAIGHT FOR 528 FEET THEN A 2° 30' CURVE TO A 3:1 FLARE AND RIPRAPPED
▬▬▬	28	NO STILLING BASIN TRAINING WALLS SLOPED AT 2.5 : 1	WEST BANK STRAIGHT AND RIPRAPPED. EAST BANK STRAIGHT FOR 528 FEET THEN A 2° 30' CURVE TO A 3:1 FLARE AND RIPRAPPED (FINAL CONFIGURATION)

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PROVINCE OF MANITOBA
DEPARTMENT OF AGRICULTURE AND CONSERVATION
WATER CONTROL AND CONSERVATION BRANCH

RED RIVER FLOODWAY
OUTLET CONTROL WORKS

RED RIVER VELOCITY DISTRIBUTION
137,000 C F S
MODEL B MODIFIED

H.G. ACRES & COMPANY LIMITED

DATE DECEMBER 1962

PLATE 8

SK-940-A-128