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Waterways Experiment
Station

Chute Spillway for Big Sioux River, Sioux Falls, South Dakota

Hydraulic Model Investigation

by Deborah R. Cooper

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DTIC QUALITY INSPECTED 3

Prepared for U.S. Army Engineer District, Omaha

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Waterways Experiment Station
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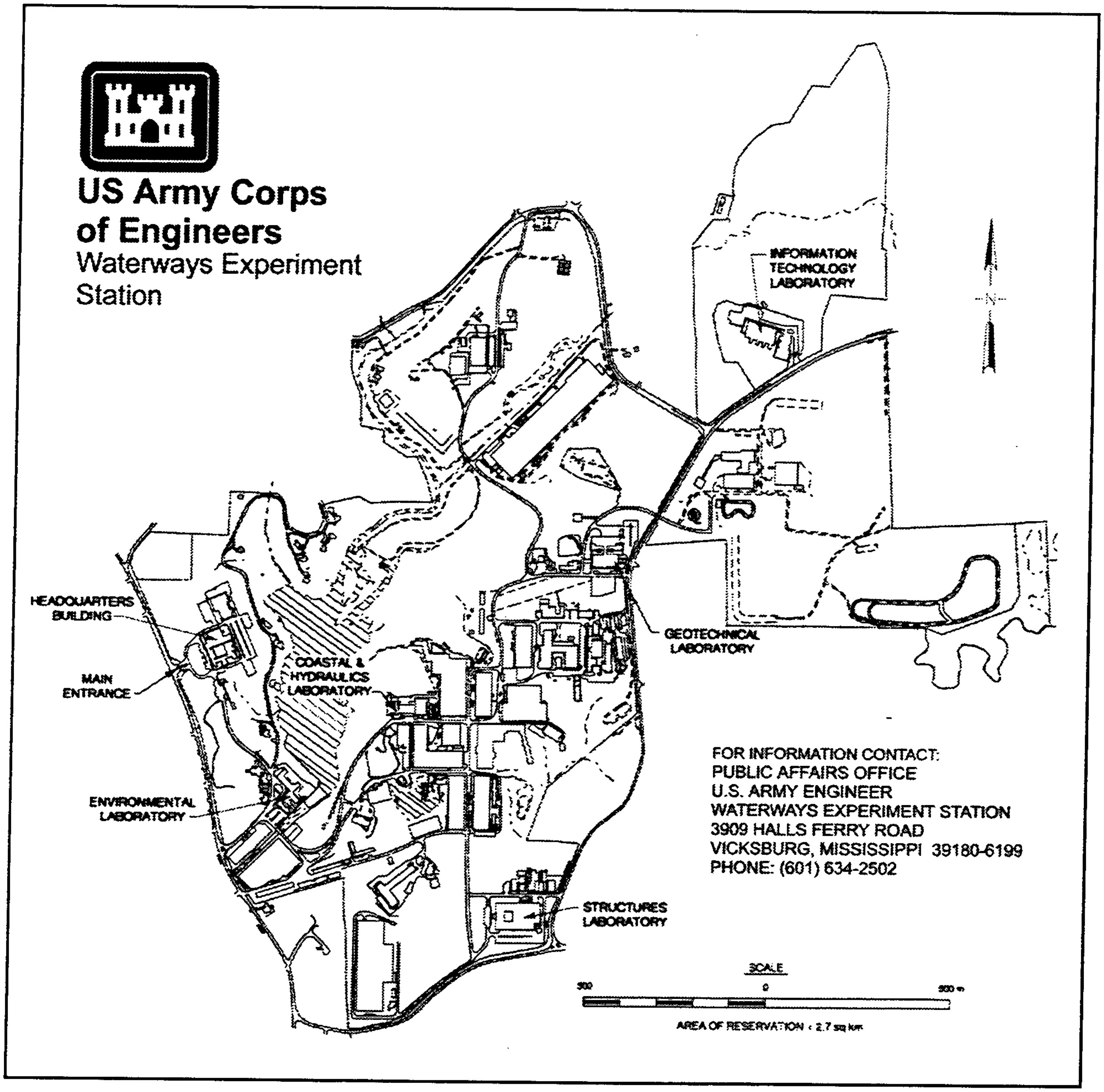

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Contents

Preface

The investigation reported herein was authorized by Headquarters, U.S. Army Corps of Engineers, on 3 June 1994 at the request of the U.S. Army Engineer District, Omaha.

The studies were conducted in the Hydraulics Laboratory (HL) of the U.S. Army Engineer Waterways Experiment Station (WES) during the period June 1994 to April 1995 under the direction of Messrs. F. A. Herrmann, Jr., Director, HL; R. A. Sager, Assistant Director, HL; and G. A. Pickering, Chief of the Hydraulic Structures Division (HSD), HL. The experiments were conducted by Mrs. D. R. Cooper, Mr. R. Bryant, Jr., and Mr. E. L. Jefferson of the Spillways and Channels Branch, HSD, under the direct supervision of Mr. N. R. Oswalt, Chief of the Spillways and Channels Branch. This report was prepared by Mrs. Cooper.

During the course of the investigation Messrs. W. Mellema and A. Swoboda of the U.S. Army Engineer Division, Missouri River, R. Buchholz, J. McClenathan, W. Dorough, W. Stern, L. Shaw, and M. Barnes of the U. S. Army Engineer District, Omaha, R. Dridge, J. Conley, and B. Pearce of the U.S. Army Engineer District, Kansas City, and R. Berkland and D. Jackson, City of Sioux Falls engineers, visited WES to discuss the results of the investigation and correlate these results with current design studies.

Messrs. Mickey Simmons and Chuck Hopkins, Directorate of Public Works (DPW), WES, constructed the chute spillway. The following DPW craftsmen molded overbank contours and river contours in the model: Messrs. Dan Barnes, Dennis Beausoliel, Charles Brown, Herman Brown, James Carpenter, Kenneth Chiplin, Clarence Drayton, Vincent Durman, Carl Gaston, Avery Harris, Frank James, William Kelly, Arnold Taylor, Willie Thomas, Stacey Washington, and Charles Wilson.

This report is being published by the WES Coastal and Hydraulics Laboratory (CHL). The CHL was formed in October 1996 with the merger of the WES Coastal Engineering Research Center and Hydraulics Laboratory. Dr. James R. Houston is the Director of the CHL, and Messrs. Richard A. Sager and Charles C. Calhoun, Jr., are Assistant Directors.

During the preparation and publication of this report, Dr. Robert W. Whalin was the Director of WES. COL Bruce K. Howard, EN, was Commander.

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1 Introduction

The Prototype

This report describes model experiments and results for a portion of the National Economic Development (NED) flood-control plan for the city of Sioux Falls, SD, for the Big Sioux River downstream of the Diversion Spillway Chute. A Reconnaissance Study completed in 1988 identified a Federal interest in upgrading the existing flood-control project at Sioux Falls by raising the levees. Sioux Falls is located in the southern part of South Dakota (Figure 1). The Big Sioux River flows in a southern direction through Sioux Falls to Interstate 229 before looping eastward to South Cliff Avenue where it turns to flow in a northern direction. A diversion channel intercepts the Big Sioux River just downstream of Highway 38A, bypassing the river loop flowing around Sioux Falls with its 24-m (80-ft) drop at Falls Park. The diversion channel exits into an elliptical crest (ogee) spillway that drops about 30.5 m (100 ft) into a stilling basin and the Big Sioux River channel. The total river discharge flows east from the Big Sioux River to Minnesota Avenue.

Figure 1 shows the layout of the Sioux Falls Flood-Control Project completed in 1965. The project consists of approximately 4,572 m (15,000 ft) of constructed diversion channel with levees along an existing diversion alignment. The diversion channel construction included a diversion dam with ten operating gates on the Big Sioux River, immediately downstream of the diversion channel entrance; a straight drop weir to control flows through the diversion channel; and a diversion spillway structure consisting of an elliptical crest (ogee), a 30.5-m (100-ft) vertical drop chute, and stilling basin. The diversion channel bypasses the 25.7-km (16-mile) loop of the Big Sioux River, avoiding the populated downtown area and a 24-m (80-ft) drop at the natural falls downstream of the downtown area. The Big Sioux River downstream of the diversion spillway structure was also improved, straightened, and levees constructed from Falls Park to a point 671 m (2,200 ft) downstream of North Cliff Avenue.

The original design of the diversion spillway structure was for 479 cu m/sec (17,100 cfs) with the diversion dam passing 204 cu m/sec (7,300 cfs) for a total capacity of 683 cu m/sec (24,400 cfs). The spillway structure was designed to pass the full 683 cu m/sec (24,400 cfs) should the diversion dam become

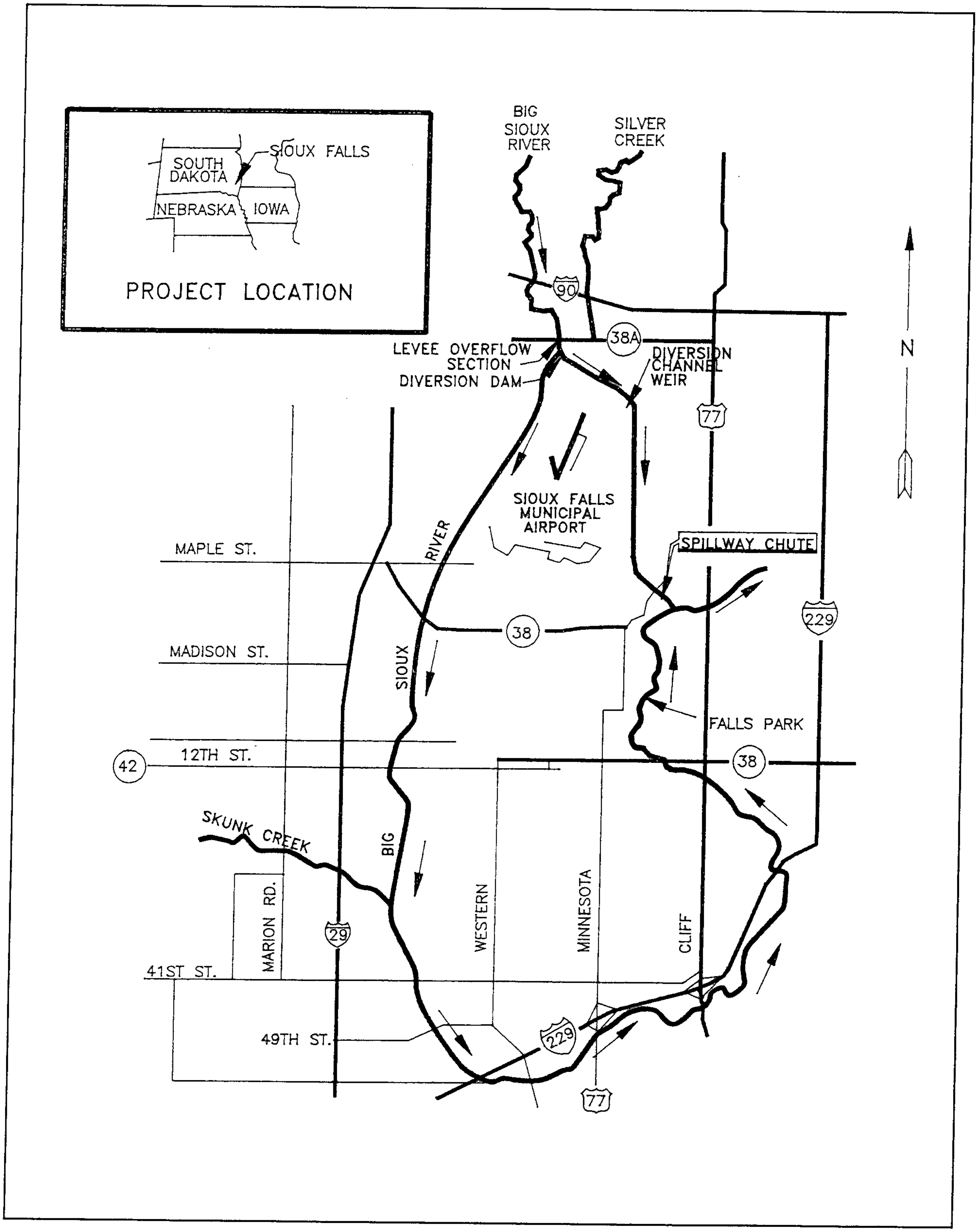

Figure 1. Location and vicinity maps

inoperative. The existing stilling basin is a Type III Bureau of Reclamation design with its basin elevation at 0.85 D_2 or elevation 1289.0.[1]

The project was originally designed to pass all flows up to 67 cu m/sec (2,400 cfs) through the diversion dam into the Big Sioux River loop to satisfy water rights for the city. Flows greater than 67 cu m/sec (2,400 cfs) were to be diverted into the diversion channel to provide flood flow relief. Currently the diversion dam gates are left closed or allow minimal flow to store water in the channel and to prevent debris affecting gate operations. This results in most flows being diverted into the diversion channel and through the diversion spillway structure, trapping sediment in the Big Sioux River upstream of the diversion dam.

The city of Sioux Falls requested U.S. Army Corps of Engineers assistance in 1969 because of a heavy snow pack and other conditions that were conducive to a major flood event. Based on Big Sioux River discharge estimates, temporary improvements were made under Operation Foresight. The flood fight included adding flashboards to the diversion spillway chute and some levee locations. Flashboards were mounted on the existing levees throughout the project including the designed overflow section to provide additional capacity.

The 1969 event had an estimated discharge of 1,120 cu m/sec (40,000 cfs) with 840 cu m/sec (30,000 cfs) passing through the diversion channel and chute and 280 cu m/sec (10,000 cfs) passing through the diversion dam. Damage to the project occurred primarily from inadequate energy dissipation in the diversion spillway chute stilling basin and levee overtopping between the diversion dam and Western Avenue on the Big Sioux River. The Bureau of Reclamation Type III basin, designed for 672 cu m/sec (24,000 cfs), withstood an 840-cu-m/sec (30,000-cfs) discharge with a tailwater below the original design tailwater for several days with minor damage. The levee across the channel from the diversion spillway chute stilling basin suffered erosion damage and was in danger of being breached. Additional earth, riprap, and sandbags were needed to prevent levee failure. Levee overtopping occurred along the Big Sioux River downstream of the Diversion Dam. The overtopping was not severe but did cause some erosion of the levee tops and side slopes.

A 1993 Feasibility Report[2] by the U.S. Army Engineer District, Omaha, examined deepening the stilling basin and increasing the stilling basin wall heights as well as raising the levees downstream of the chute. The model study was used to determine an alternative to building a new, deeper basin resulting in a savings of $1 million.

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[1] All elevations (el) and stages cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD). To change elevations to meters, multiply by 0.3048.

[2] U.S. Army Engineer District, Omaha. (1993 (Nov)). "Feasibility report engineering appendix - Vols I and II, Local flood protection, Big Sioux River and Skunk Creek at Sioux Falls, South Dakota," Omaha, NE.

Purpose and Scope of the Model Study

The diversion spillway chute was designed by the Omaha District using the program WASURO developed by the U.S. Army Engineer District, Los Angeles, and adapted to the microcomputer by the U.S. Army Engineer Waterways Experiment Station (WES). The WASURO program computes water depths for supercritical flow and adjusts the water depths for the slope angle of steep channels and for air entrainment. The program allows input of either an assumed effective roughness, k_s, or Manning's n value. Calculations using the output from the WASURO computer runs indicated that, based on the calculated design tailwater rating curve, the existing basin is not low enough to provide satisfactory energy dissipation for discharges higher than 776 cu m/sec (27,700 cfs) (a 50-year event). Therefore, alternatives for modification to the stilling basin were considered.

Three stilling basin types were investigated by the Omaha District: the standard Corps of Engineers (COE) stilling basin described in EM 1110-2-1603 [1] for spillways; the Bureau of Reclamation Type III impact basin; and the Bureau of Reclamation Type II basin for high spillways. The design of the chute stilling basin was based on sound engineering procedures; however, a model study was considered essential to verify the hydraulics of the proposed stilling basin design and to examine the significant energy dissipation problems expected downstream of the stilling basin. The model study was also necessary to optimize chute and stilling basin features to develop the most economical design. The following information was obtained from the model:

a. Flow characteristics and stilling basin performance.

b. Water-surface elevations to design chute wall heights to prevent overtopping.

c. Water-surface elevations and wave amplitudes to design downstream levee heights to prevent overtopping.

d. Riprap requirements for channel protection downstream of the structure.

e. Wave heights of exiting flow for design of riprap protection of the levees.

Presentation of Data

In the presentation of experiment results, no attempt is made to introduce the data in the chronological order in which the experiments were conducted on the

[1] Headquarters, U.S. Army Corps of Engineers. (1990 (16 Jan)). "Hydraulic design of spillways," USACE Publication Depot, Hyattsville, MD.

model. Instead, as each element of the structure is considered, all experiments conducted thereon are discussed in detail. All model data are presented in terms of prototype equivalents. All experiments are discussed in Part 3 of this report.

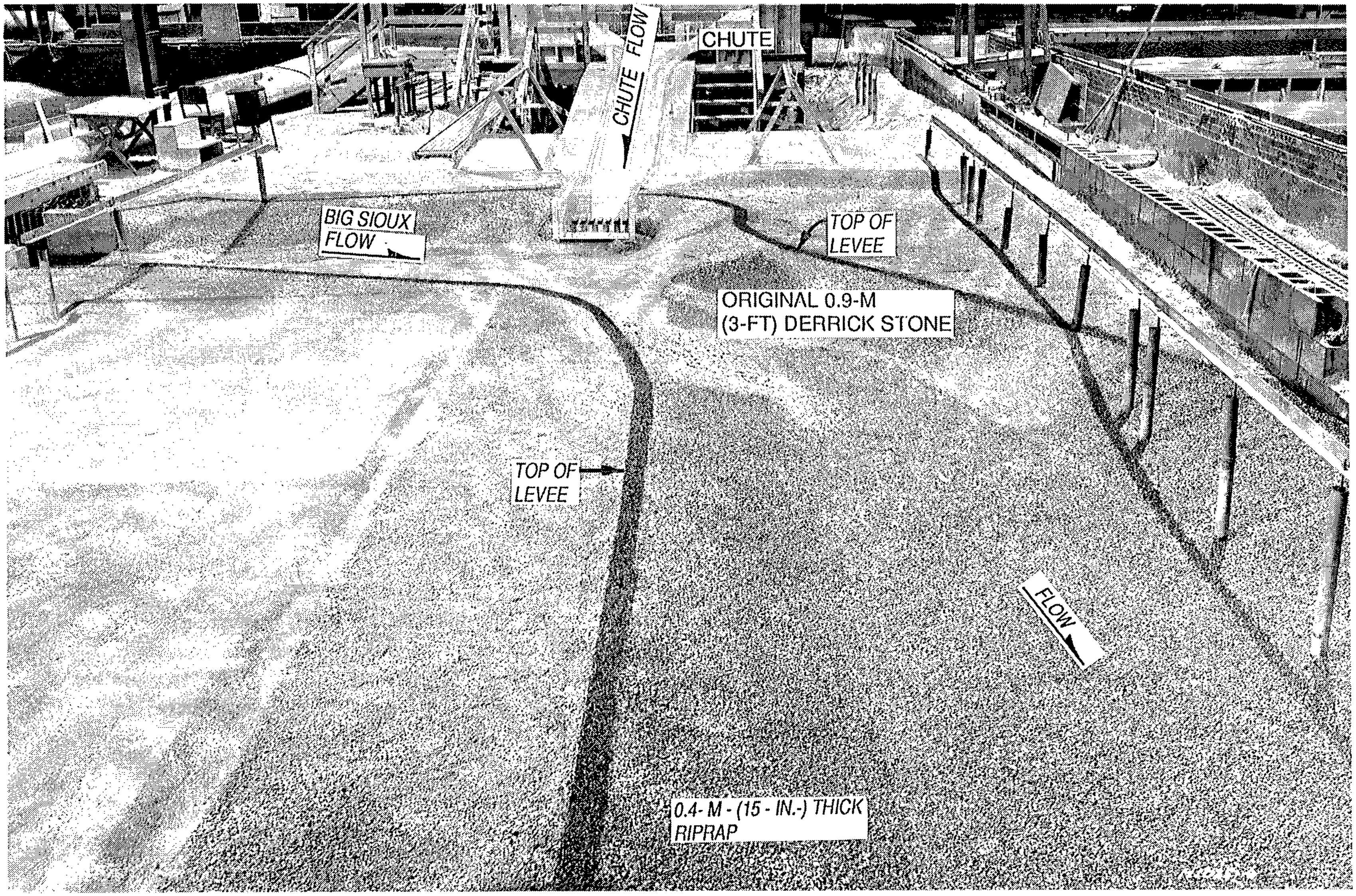
2 The Model and Experiment Procedure

Description

Originally the 1:30-scale model (Figures 2 and 3, Plate 1) reproduced an approach area 146 m (480 ft) wide extending 91 m (300 ft) upstream from the diversion spillway crest, the highway bridge, 259-m- (851-ft-) long diversion chute, chute blocks, the 32-m- (105-ft-) long stilling basin and basin elements, the Big Sioux River confluence, and an exit area 183 m (600 ft) wide extending 213 m (700 ft) downstream from the end sill. To contain all flood flows, the existing chute walls were raised 3.6 m (12 ft) from sta 19+55 to sta 16+00 and 1.8 m (6 ft) from sta 16+00 to sta 11+08.16. The spillway (Figure 3) was molded in concrete. The South Dakota State Highway 115 bridge and chute walls (Figure 3a) were fabricated of clear plastic (Plexiglas). The upstream approach, floor of the chute, chute blocks, baffle blocks, and the end sill were fabricated of plywood and painted. Previous investigations at WES determined the painted surface simulated an n value of 0.0158. Prototype n value for the chute was 0.015. The exit channel immediately downstream of the chute end sill was molded in pea gravel and grouted. The side slopes, opposite bank, and Big Sioux River were molded in rock simulating riprap and derrick stone. The top of the overbank was set at the elevation of the top of the levees (el 1329.1) and graded in gravel. The levee top elevation in the 1993 Feasibility Report was designed for the 100-year flood event on the Big Sioux River.

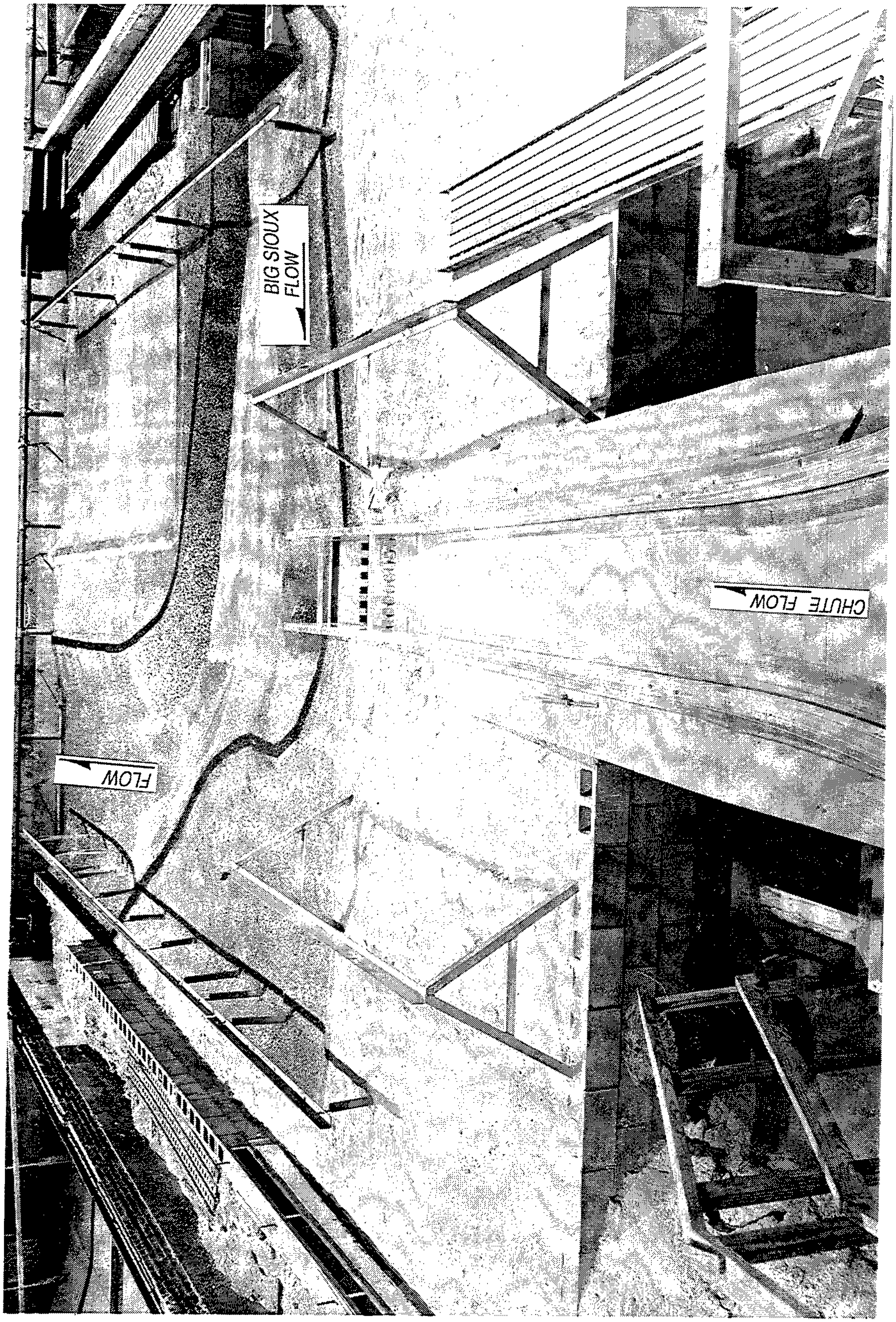
Appurtenances and Instrumentation

Water used in the operation of the model was supplied by pumps, and discharges were measured with venturi meters. The tailwater in the downstream end of the model was controlled by an adjustable tailgate. Water-surface elevations were obtained with point gages mounted on the chute walls, tripods, and rails set to grade. Velocities were measured with a Nixon 402 digital flowmeter.



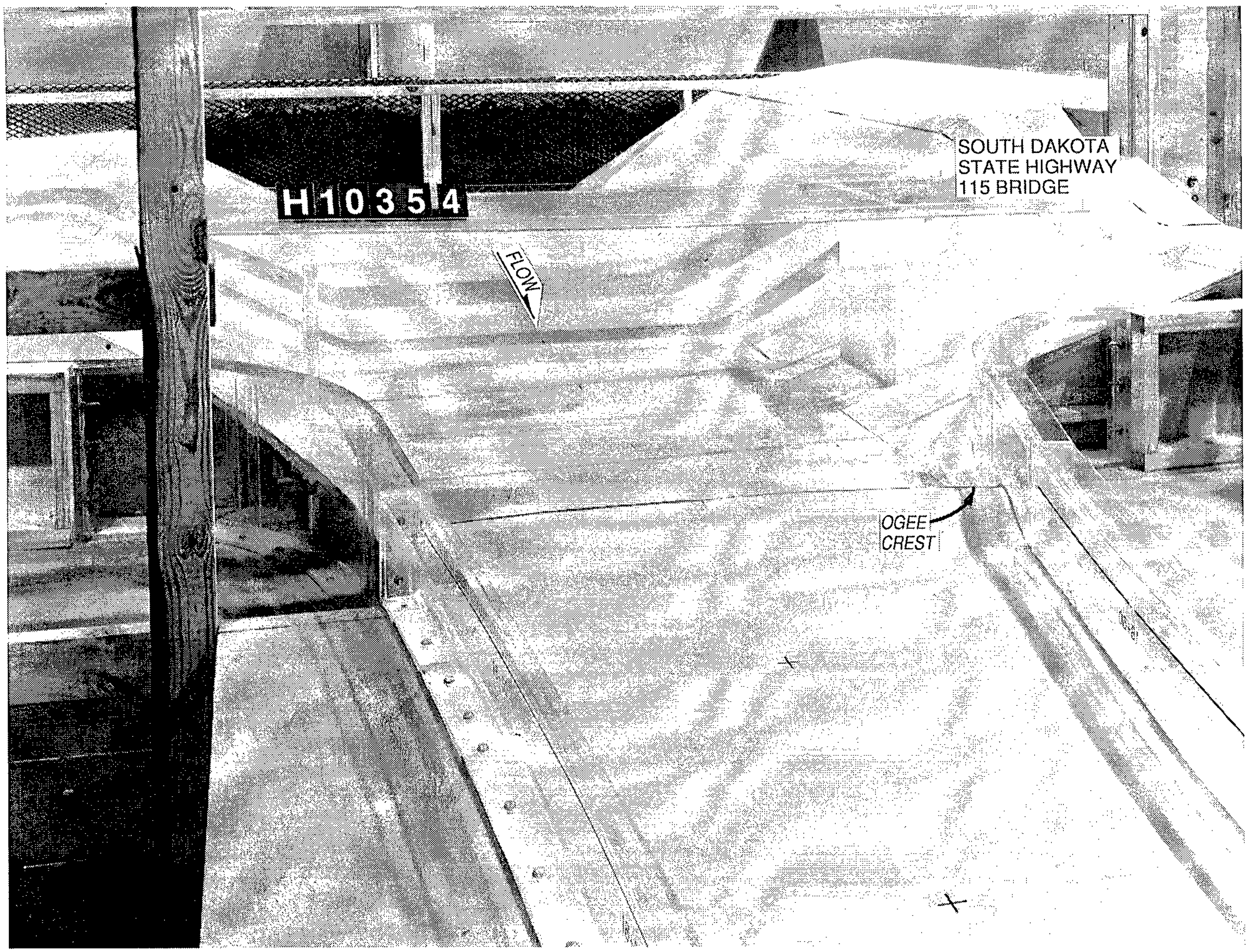
a. Looking upstream

Figure 2. Original design, 1:30-scale model (Continued)



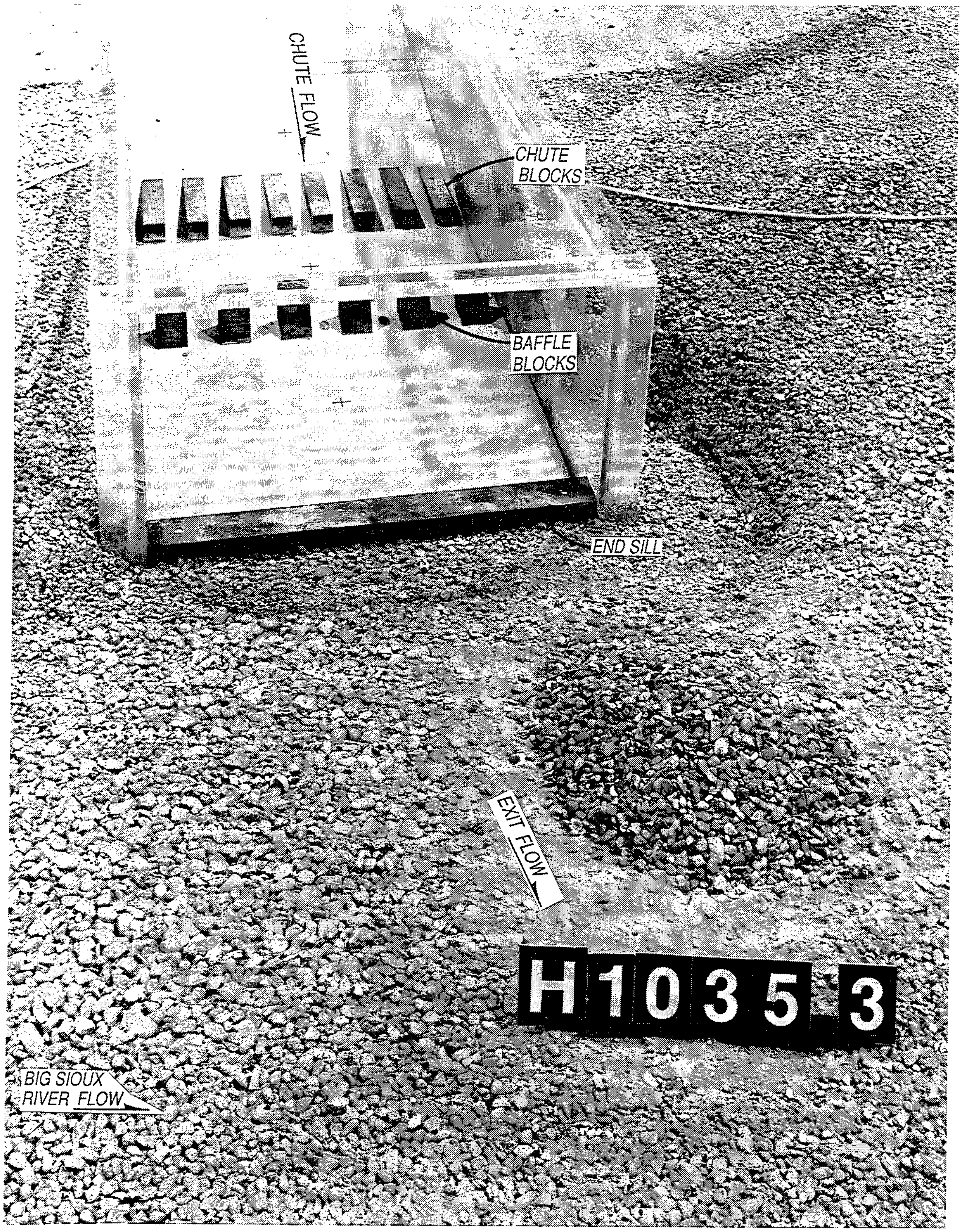
b. Looking downstream

Figure 2. (Concluded)



a. Chute spillway, bridge, and approach

Figure 3. Original design looking upstream (Continued)



b. Chute stilling basin

Figure 3. (Concluded)

Scale Relations

The accepted equations of similitude, based upon the Froudian relations, were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and the prototype. General relations for the transference of model data to prototype equivalents are presented in the following tabulation:

Dimension	Ratio	Scale Relations Model:Prototype
Length	$L_r = L$	1:30
Area	$A_r = L_r^2$	1:900
Velocity	$V_r = L_r^{1/2}$	1:5.477
Discharge	$Q_r = L_r^{5/2}$	1:4929.5
Time	$T_r = L_r^{1/2}$	1:5.477

Because of the nature of the phenomena involved, certain of the model data can be accepted quantitatively, while other data are reliable only in a qualitative sense. Measurements in the model of discharges, water-surface elevations, velocities, and resistance to displacement of riprap material can be transferred quantitatively from model to prototype by means of these scale relations. Evidence of scour of the model bed, however, is to be considered only as qualitatively reliable since it has not yet been found possible to reproduce quantitatively in a model the relative extent of erosion that occurs in the prototype with cohesive or noncohesive fine-grained bed material. Data on scour tendencies provided a basis for determination of the relative effectiveness of the different designs and indicated the areas most subject to degradation and deposition.

Experiment Procedure

Experiments were conducted in the model to observe the flow patterns, velocities, discharges, and overall hydraulic performance of the chute spillway, stilling basin, and exit channel. Various constant discharges were introduced into the model, the tailwater was set, and the river was allowed to stabilize. Sufficient time was allowed for stabilization of the inflow upstream of the spillway structure. Water-surface elevations were measured at various stations along the chute and river as shown in Plates 2 and 3. Tailwater elevations were measured at a point 152 m (500 ft) downstream from the end sill (Plate 3). The tailwater rating curve used in these experiments is shown in Plate 4. The existing tailwater rating curve is considerably lower than the original design tailwater rating curve. Water-surface profile elevations and velocities were measured in the chute as well as in the river.

3 Experiments and Results

Chute Design

Initial experiments were run in the model to verify the model design (n value and slope). A discharge of 658 cu m/sec (23,500 cfs) was introduced into the model chute, and water-surface elevation data were recorded at various stations as indicated in Plate 2. The data were then compared with high-water marks measured during the 1969 flood (chute discharge, Q_C, 658 cu m/sec (23,500 cfs)) provided by the Omaha District. Model water-surface data compared favorably to the Omaha District water-surface profile data in the chute, but were a little higher than the prototype in the approach. The higher water-surface elevations in the approach were attributed to the value of the model Manning's n value of 0.0158 in the model approach and chute. The prototype n value for the chute was 0.015. The prototype n value for the approach was considerably less; therefore, the model approach was rougher than the prototype approach causing model water-surface elevations to be higher in the model than in the prototype. Plots comparing the 1969 high-water mark water-surface profile with the water-surface profile measured in the model are shown in Plates 5-7 and Table 1. Q_C is the discharge in the chute and Q_R is the discharge in the Big Sioux River. Because the model chute water-surface profile compared favorably to the prototype water-surface profile, the model chute slope did not have to be adjusted. Water-surface profiles measured in the model for existing conditions in the chute are plotted in Plates 8-11 and data recorded in Tables 2-5. To contain all flood flows, the model chute walls were raised 3.6 m (12 ft) from sta 19+55 to sta 16+00 and 1.8 m (6 ft) from sta 16+00 to sta 11+08.16. The Omaha District stated the water-surface profiles measured with the 500-year flood flow would be used to set the maximum height of the chute walls. To contain surges from the 500-year flood (1,044 cu m/sec (37,300 cfs) in the chute (Q_C), 812 cu m/sec (29,000 cfs) in the Big Sioux River (Q_R)), data measured in the model indicated the stilling basin walls from sta 13+64.21 to sta 11+08.16 should be raised a total of 6.4 m (21 ft) from el 1326.0 to el 1347.0.

A discharge of 812 cu m/sec (29,000 cfs) was run through the chute and the Big Sioux River discharge was varied to determine sensitivity of the flow patterns at the confluence of the chute and exit channel to the Big Sioux River flow. The Big Sioux River discharges of 168, 224, 280, and 336 cu m/sec (6,000, 8,000, 10,000, and 12,000 cfs, respectively) with appropriate tailwater elevations were set and flow patterns, velocities, and water-surface elevations were measured for existing conditions. Surface, middepth, and bottom velocity measurements indicated that increasing the discharge of the Big Sioux River with respective tailwater elevations did not significantly increase turbulence and velocities. Results of these experiments are shown in Tables 6-9 and Plates 12-23 and 24-27. The depth, d_1, and velocity, v_1, at the toe of the hydraulic jump, and depth, d_2, and velocity, v_2, of the hydraulic jump (d_2 and v_2 measured over the end sill at the center line and about 7.6 m (25 ft) left and right of the center line) and depths and velocities at various locations along the downstream channel were measured in the model. D_1 is the tailwater depth entering the stilling basin, v_1 is the velocity at d_1, d_2 is the hydraulic jump secant depth and v_2 is the velocity at d_2. Water-surface elevations are plotted in Plates 28-31 and shown in Table 10.

Experiments were conducted to measure water-surface profiles and velocities for existing conditions for the 10-, 50-, 100- and 500-year flood events in the model chute and the exit channel. Discharges for each flood event in the chute and in the Big Sioux River are shown in Table 11.

The water-surface elevation and velocity 0.3 m (1 ft) below the surface, at middepth, and above the channel invert were measured in the exit channel for the conditions in Table 12. Flow conditions in the stilling basin for the 50- and 500-year and 1969 floods are shown in Photos 1-3. Flow began to overtop the stilling basin walls at the 1969 flood discharge of 812 cu m/sec (29,000 cfs) (Photo 2), and a considerable amount of flow surged over the tops of the stilling basin walls at the 500-year discharge of 1,044 cu m/sec (37,300 cfs). Water-surface elevations are plotted in Plates 32-43 and shown in Tables 13-17. Surface, middepth, and bottom velocity measurements are plotted in Plates 44-79 and are shown in Tables 18-29. Wave height data are shown in Table 30.

The original (type 1) stilling basin provided adequate energy dissipation up to the 100-year and 1969 chute discharges. The stilling basin did not fully dissipate the energy for the 500-year event, but the flow did not directly impact the opposite bank because of the large flow from the Big Sioux entering the channel. For the 500-year event, the opposite levee bank (top el 1327.0) was overtopped by wave action leaving the stilling basin, causing failure of the opposite bank. Flow impact on the opposite bank will be discussed later in the "Channel Realignment" section of this report. Additional d_1, v_1, d_2 and v_2 measurements are shown in Plates 80-82 and Table 31. Velocity and depth data were used to design modifications to the stilling basin walls to contain surges and to the stilling basin elements to improve energy dissipation. Based on measurements taken with the type 1 stilling basin, the stilling basin wall height should be increased 6.4 m (21 ft) to contain surges from the 500-year flood. A second row of baffle piers was added to the existing stilling basin. This was designated the type 2 stilling basin (Plate 83). The second row of baffle piers increased turbulence in the stilling basin and increased surging in the basin. At the 500-year event, standing waves that formed in the channel continued downstream.

The water-surface elevation and velocity 0.3 m (1 ft) below the surface, at middepth, and above the channel invert were measured in the exit channel for the conditions shown in Table 12 with the type 2 design stilling basin. Flow conditions in the stilling basin for the 50- and 500-year and 1969 floods are shown in Photos 4-6. Flow began to overtop the stilling basin walls (modeled at el 1332.0) at the 1969 flood discharge of 812 cu m/sec (29,000 cfs) (Photo 5), and a considerable amount of flow surged over the tops of the stilling basin walls at the 500-year discharge of 1,044 cu m/sec (37,300 cfs). Water-surface elevations are plotted in Plates 84-89 and shown in Tables 32-34. Surface, middepth, and bottom velocity measurements are plotted in Plates 90-107 and are shown in Tables 35-40. Comparing the velocities with the type 1 and 2 stilling basins indicates a slight increase in surface velocities and no significant change in the middepth and bottom velocities with the type 2 stilling basin. The depth (d_1) and velocity (v_1) at the toe of the hydraulic jump, depth (d_2) and velocity (v_2) of the hydraulic jump (d_2 and v_2 measured over the end sill at the center line and about 7.6 m (25 ft) left and right of the center line), and depths and velocities at various locations along the downstream channel were measured in the model. Depth and velocity measurements are plotted in Plates 108-110 and Table 41. Wave height measurements are shown in Table 42.

The baffle piers, chute blocks, and end sill were designed by WES based on the velocity and depth measurements in the model. One row of 2.4-m- (8-ft-) high baffles and 1.7-m- (5.5-ft-) high chute blocks were installed in the stilling basin. This was designated the type 3 stilling basin (Plate 111). The new features increased surging over the stilling basin walls and produced excessive turbulence in the exit channel for the 100- and 500-year events.

Because the velocities were not significantly decreased by the modifications to the basin, and wave heights increased substantially in the exit channel, Omaha District engineers decided to examine realigning the channel and design a riprap protection plan to protect the opposite bank and downstream levees with no modification to the type 1 (original) stilling basin.

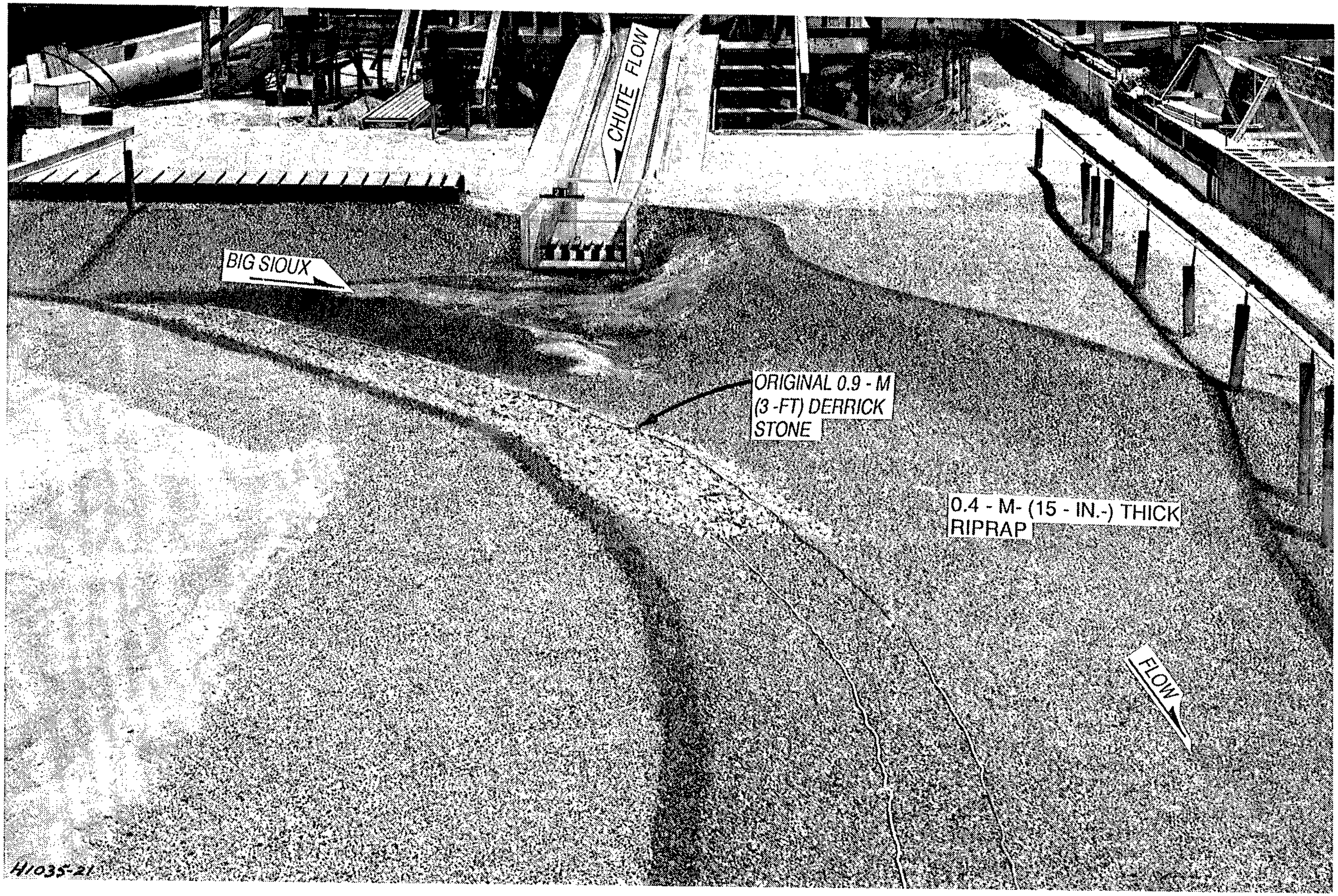
Channel Realignment

Flow impacting the opposite bank was of interest because during the 1969 flood the opposite bank failed due to flows exiting the chute and attacking the opposite bank. Flow exiting the chute and the impact of flow on the opposite bank are shown in Photos 7-9 and 10-12 for the 50-year, 1969, and 500-year floods for the type 1 (original) and type 2 stilling basins, respectively, with the existing channel alignment (Figure 2).

The type 1 (original) and 2 stilling basins provided adequate energy dissipation up to the 100-year and 1969 chute discharges and did not directly impact the opposite bank. Neither the type 1 nor type 2 basin fully dissipated the energy for the 500-year event, but the type 2 basin caused higher surges over the stilling basin walls and more turbulence exiting the stilling basin (comparing Photos 9 and 12) as indicated by the slight increase of surface velocities. While flow did not directly impact the opposite bank because of the large flow from the Big Sioux entering the channel, for the 500-year event, the bank opposite the levee (top el 1327.0) was overtopped by wave action caused by flow exiting the stilling basin (Photos 9 and 12). The wave action and overtopping of the levees caused failure of the opposite bank.

The channel was realigned by moving the opposite bank back approximately 24 m (80 ft) (Plate 112) and raising the opposite bank top levee el from el 1327.0 to el 1329.1. The existing and proposed exit channel realignments are shown in Plates 1 and 112, respectively. Widening the channel allowed flow exiting the chute and entering from the Big Sioux River to remain in the channel away from the opposite bank, decreasing bottom velocities 500 ft downstream of the end sill. Water-surface elevations; wave heights; and surface, middepth, and bottom velocities were measured with the type 1 (original) stilling basin for the 10-year, 50-year, 1969, and 500-year floods. Water-surface data are shown in Plates 113-116 and Table 43. Velocities in the realigned exit channel are shown in Plates 117-128 and Tables 44-47. Wave heights in the realigned exit channel are shown in Tables 48 and 49. Flow exiting the chute and the impact of flow on the opposite bank are shown in Photos 13-16 for the 10- and 50-year, 1969, and 500-year floods with the realigned channel and type 1 (original) stilling basins.

Riprap protection gradation was based on the gradation for a 0.9-m (3-ft) (prototype) derrick stone as specified in the November 1969 rehabilitation contract from sta 135+50 to sta 138+00 and 381-mm (15-in.) riprap layer thickness (gradation provided by Omaha District) along the riverbank. The type 1 (original) riprap design consisted of a 381-mm- (15-in.-) thick blanket (Class A) simulating protective stone in the model with a D_{50min} of 279 mm (11 in.) placed along the Big Sioux River downstream to sta 135+50, a 914-mm- (36-in.-) thick blanket (Class B) simulating derrick stone with a D_{min} of 686 mm (27 in.) placed from sta 135+50 to sta 138+00, followed by the 381-mm- (15-in.-) thick blanket (Class A) as shown in Plate 129 and Figures 4 and 5. Gradation curves for the stone used are shown in Plates 130 and 131. A total discharge of 1,856 cu m/sec (66,300 cfs) - 1,044 cu m/sec (37,300 cfs) in the chute and 812 cu m/sec (29,000 cfs) in the Big Sioux River - was run through the model for 60 hr (prototype). The protection failed at the downstream interface of the 0.9-m (3-ft) derrick stone and 381-mm (15-in.) riprap (Figure 6). A 27-m- (90-ft-) wide transition layer of 686-mm- (27-in.-) thick riprap (Class C) simulating protective stone in the model with a D_{50min} of 279 mm (11 in.) was placed between the derrick stone and the 381-mm (15-in.) riprap. This design was designated the type 2 design stone protection (Plate 132). The gradation curve for the 686-mm- (27-in.-) thick riprap is shown in Plate 133. A total discharge of 1,856 cu m/sec (66,300 cfs) - 1,044 cu m/sec (37,300 cfs) in the chute and 812 cu m/sec (29,000 cfs) in the Big Sioux River - was run through the model for 60 hr (prototype). The type 2 protection remained stable and is recommended for prototype construction.

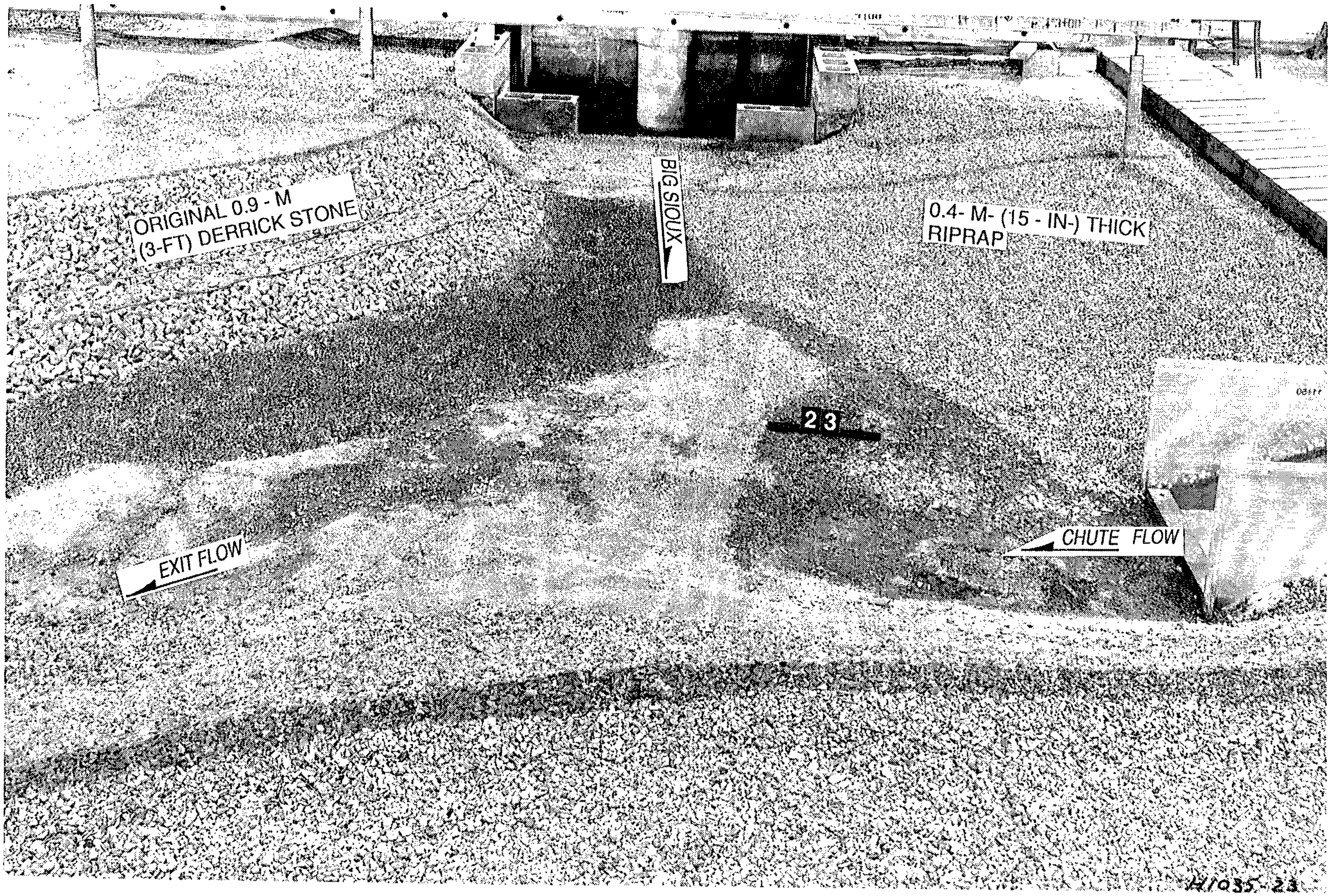


a. Looking upstream

Figure 4. Realigned channel design, riprap protection (Sheet 1 of 4)

b. Looking downstream

Figure 4. (Sheet 2 of 4)



c. Looking upstream into mouth of the Big Sioux River

Figure 4. (Sheet 3 of 4)

d. Looking at realigned opposite bank

Figure 4. (Sheet 4 of 4)

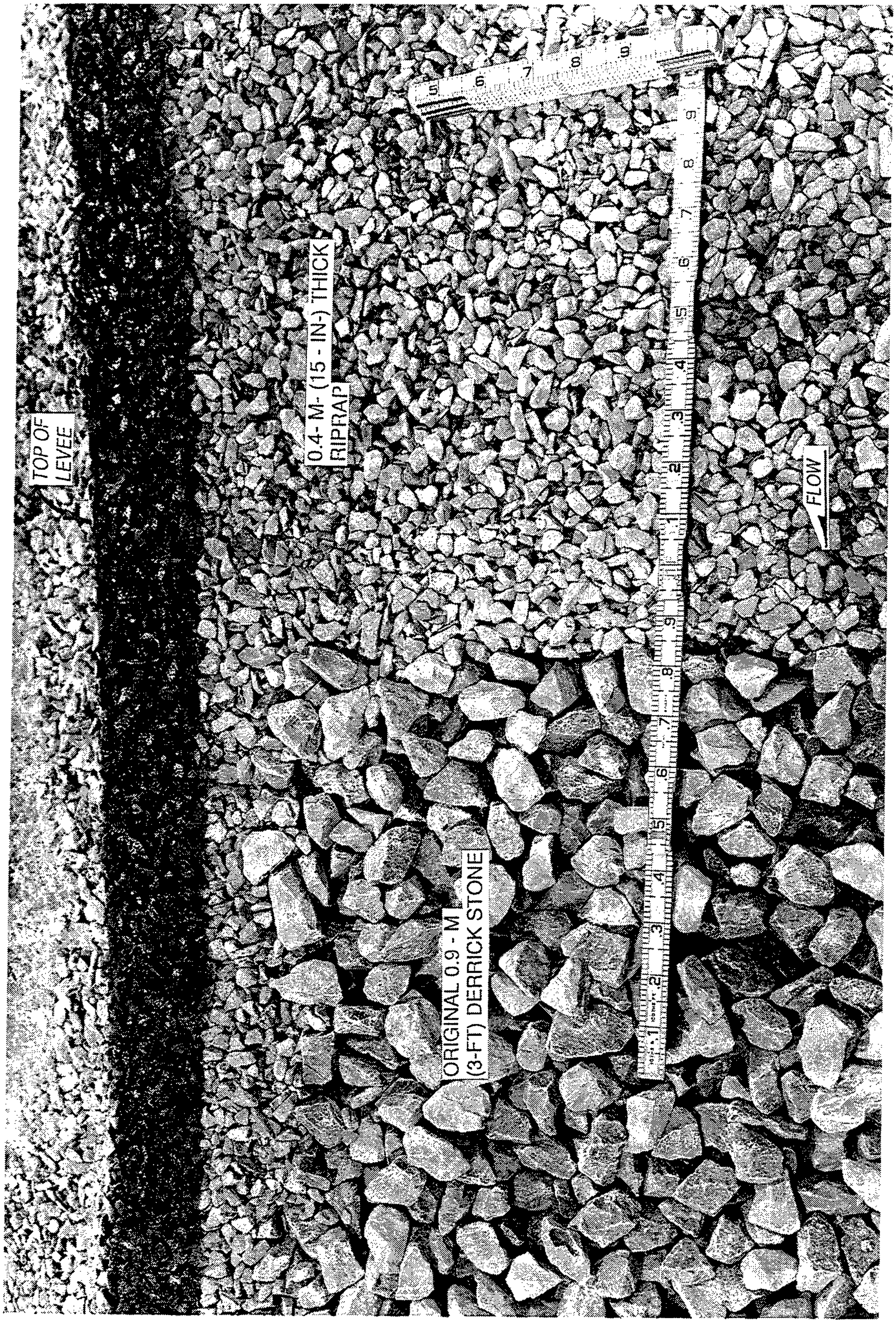


Figure 5. Original design, derrick stone/riprap protection

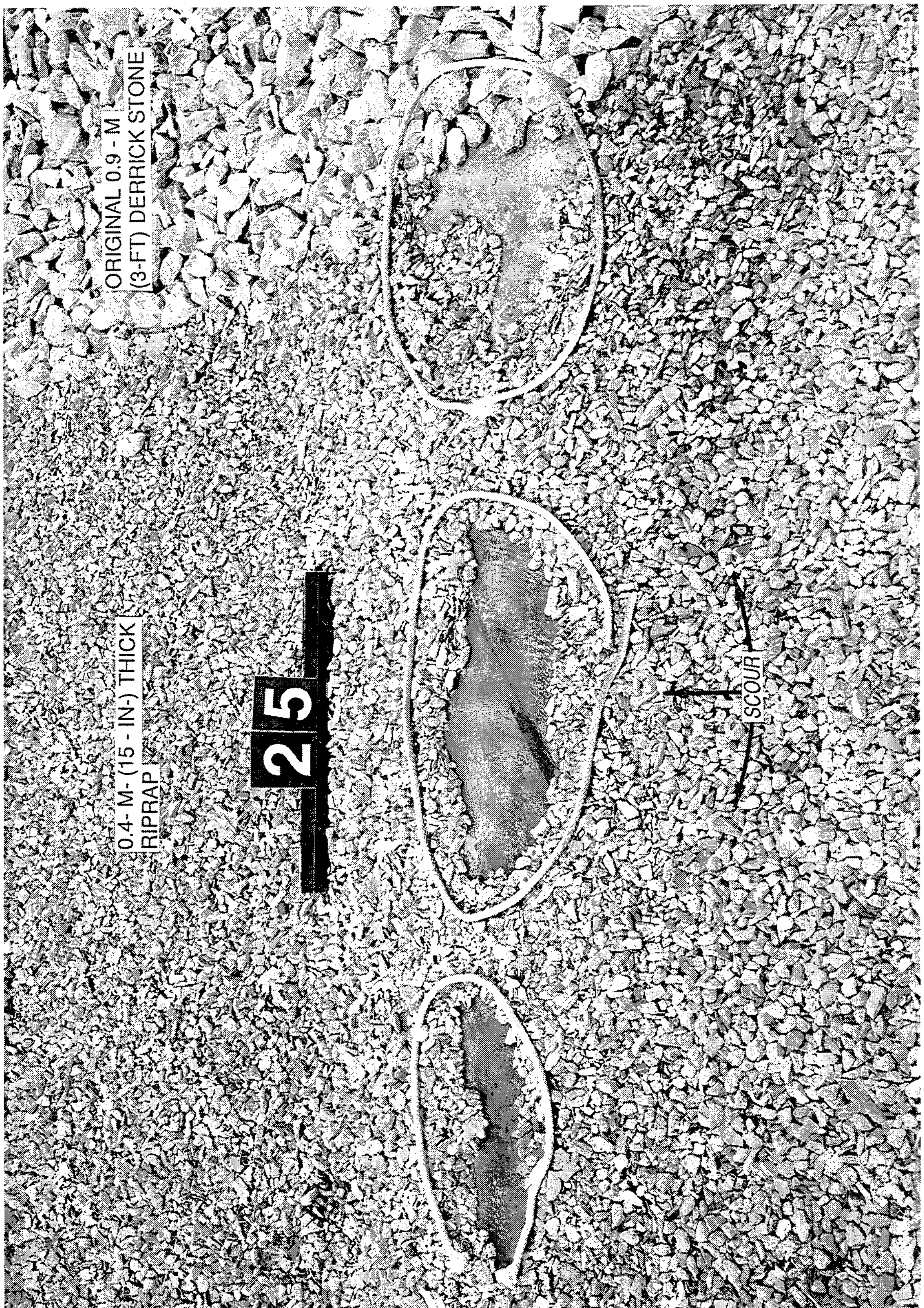


Figure 6. Scour of 0.38-m- (15-in.-) thick layer on realigned opposite bank, Q_C = 1,044 cu m/sec (37,300 cfs), Q_R = 812 cu m/sec (29,000 cfs), tailwater el 1327.0, t = 60 hours

Stilling Basin Wall Heights

The maximum surge of flow in the stilling basin was measured with the wall heights increased to confine all flow in the basin and without wall heights increased to contain all flow in the basin for the 500-year and 100-year floods, respectively, as requested by the U.S. Army Engineer Division, Missouri River. The maximum water-surface elevation with and without the wall heights increased was 1346.9 at the 500-year flood flow. This indicated that the walls in the stilling basin will have to be increased to at least el 1347.0 to contain the 500-year flood. Data are recorded in Tables 50 and 51, respectively.

4 Conclusions

Initial experiments were run in the model to verify the model design (n value and slope). A discharge of 658 cu m/sec (23,500 cfs) was introduced into the model chute and water-surface elevation data were recorded at various stations. The data were then compared with high-water marks measured during the 1969 flood (chute discharge 658 cu m/sec (23,500 cfs)). Model water-surface data compared favorably to the Omaha District 1969 flood high-water mark water-surface profile data in the chute, indicating the model chute roughness was simulating the prototype chute roughness and the model chute slope did not have to be adjusted. Water-surface elevations in the approach were a little higher than the prototype because the model approach was considerably rougher than the prototype approach.

A discharge of 812 cu m/sec (29,000 cfs) was run through the chute and the Big Sioux River discharge was varied to determine sensitivity of the flow patterns at the confluence of the chute and exit channel to the Big Sioux River flow. The Big Sioux River discharges of 168, 224, 280 and 336 cu m/sec (6,000, 8,000, 10,000 and 12,000 cfs, respectively) with appropriate tailwater elevations were set and flow patterns, velocities, and water-surface elevations were measured for existing conditions. Surface, middepth, and bottom velocity measurements indicated that increasing the discharge of the Big Sioux River with respective increases in tailwater elevations did not significantly increase turbulence or velocities.

The original (type 1) stilling basin provided adequate energy dissipation up to the 100-year and 1969 flood chute discharges. Although the stilling basin did not fully dissipate the energy for the 500-year event, flow exiting the chute did not directly impact the opposite bank because of the large flow from the Big Sioux entering the channel. At the 500-year event, the opposite levee bank (top el 1327.0) was overtopped by wave action, causing failure of the opposite bank. Flow began to overtop the stilling basin walls at the 1969 flood discharge of 812 cu m/sec (29,000 cfs) (Photo 2), and a considerable amount of flow surged over the tops of the stilling basin walls at the 500-year discharge of 1,044 cu m/sec (37,300 cfs). To contain all flood flows, the chute walls were raised 3.6 m (12 ft) from sta 19+55 to sta 16+00 and 1.8 m (6 ft) from sta 16+00 to sta 11+08.16. The Omaha District stated the water-surface profiles measured with the 500-year flood flow would be used to set the maximum height of the chute walls. To contain surges from the 500-year flood, data measured in the model indicated the stilling basin walls from sta 13+64.21 to sta 11+08.16 should be raised a total of 6.4 m (21 ft) to contain surges from the 500-year flood.

A second row of baffle piers was added to the existing stilling basin. This was designated the type 2 stilling basin (Plate 83). The second row of baffle piers increased turbulence in the stilling basin and increased surging in the basin. At the 500-year event, standing waves that formed in the channel continued well downstream.

One row of 2.4-m- (8-ft-) high baffles and 1.7-m- (5.5-ft-) high chute blocks were installed in the stilling basin. This was designated the type 3 stilling basin (Plate 111). The new features increased surging over the stilling basin walls and produced more turbulence in the exit channel for the 100- and 500-year events.

The type 1 (original) and 2 stilling basins provided adequate energy dissipation up to the 100-year and 1969 chute discharges and did not directly impact the opposite bank. Neither the type 1 nor type 2 basin fully dissipated the energy for the 500-year event, but the type 2 basin caused higher surges over the stilling basin walls and more turbulence exiting the stilling basin (comparing Photos 9 and 12). While flow did not directly impact the opposite bank because of the large flow from the Big Sioux entering the channel, for the 500-year event, the opposite levee bank (top el 1327.0) was overtopped by wave action caused by flow exiting the stilling basin (Photos 9 and 12). The wave action and overtopping of the levees caused failure of the opposite bank. The channel was realigned by moving the opposite bank back approximately 24 m (80 ft) (Plate 112) and raising the opposite levee to top from el 1327.0 to 1329.1. The top of the left levees remained at el 1329.1. Widening the channel allowed flow exiting the chute and entering from the Big Sioux River to remain in the channel away from the opposite bank, decreasing bottom velocities 500 ft downstream of the end sill. Modifications to the stilling basin did not improve flow conditions in the exit channel; therefore, it was recommended that the original stilling basin with the walls raised 6.4 m (21 ft) be used and the downstream channel realigned.

Riprap protection gradation was based on the gradation for a 0.9-m (3-ft) (prototype) derrick stone as specified in the November 1969 rehabilitation contract from sta 135+50 to sta 138+00 and 381-mm (15-in.) riprap layer thickness (gradation provided by Omaha District) along the river bank. The type 1 (original) riprap design consisted of a 381-mm- (15-in.-) thick blanket (Class A) simulating protective stone in the model with a D_{50min} of 279 mm (11 in.) placed along the Big Sioux River downstream to sta 135+50, a 914-mm- (36-in.-) thick blanket (Class B) simulating derrick stone with a D_{min} of 686 mm (27 in.) placed from sta 135+50 to sta 138+00, followed by the 381-mm- (15-in.-) thick blanket (Class A) as shown in Plate 129 and Figure 4. A total discharge of 1,856 cu m/sec (66,300 cfs) - 1,044 cu m/sec (37,300 cfs) in the chute and 812 cu m/sec (29,000 cfs) in the Big Sioux River - was run through the model for 60 hr (prototype). The protection failed at the downstream interface of the 0.9-m (3-ft) derrick stone and 381-mm (15-in.) riprap (Figure 6). A 27-m- (90-ft-) wide transition layer of 686-mm- (27-in.-) thick riprap (Class C) simulating protective stone in the model with a D_{50min} of 279 mm (11 in.) was placed between the derrick stone and the 381-mm (15- in.) riprap. This design was designated the type 2 design stone protection (Plate 132). A total discharge of 1,856 cu m/sec (66,300 cfs) - 1,044 cu m/sec (37,300 cfs) in the chute and 812 cu m/sec (29,000 cfs) in the Big Sioux River - was run through the model for 60 hr (prototype). The type 2 design stone protection remained stable and is recommended for prototype construction.

Summarizing, the chute walls should be raised 3.6 m (12 ft) from sta 19+55 to sta 16+00 and 1.8 m (6 ft) from sta 16+00 to sta 13+64.21. The stilling basin should not be modified. The stilling basin walls should be raised 6.4 m (21 ft) from sta 13+64.21 to sta 11+08.16 to contain surges from the 500-year flood. The downstream exit channel levee should be moved back 24 m (80 ft), and 0.9-m (3-ft) derrick stone protection should extend at least 213 m (700 ft) downstream from the end sill, followed by a 27-m- (90-ft-) long transition of 686-mm- (27-in.-) thick riprap. All other overbank areas should be protected up to the tops of the levees (el 1329.1) with 381-mm- (15-in.-) thick riprap.

Table 1
Water-Surface Elevations in Chute, Q_C = 658 cu m/sec (23,500 cfs), Q_R = 280 cu m/sec (10,000 cfs), Tailwater El 1324.5

Sta	Location	1969 Flood High-Water Mark	WES Physical 1:30 Model
19+54.92	Left wall	1421.6	1422.4
	Center line	-	1422.1
	Right wall	1421.5	1422.8
19+48.30	Left wall	1421.7	1422.4
	Center line	-	1422.4
	Right wall	1421.5	1422.2
19+30.91	Left wall	1420.7	1422.0
	Center line	-	1421.9
	Right wall	1420.5	1421.9
19+18.23	Left wall	1419.8	1421.5
	Center line	-	1421.4
	Right wall	1419.8	1421.1
18+33.79	Left wall	1408.2	1409.5
	Center line	-	1408.6
	Right wall	1407.9	1408.6
17+83.79	Left wall	1402.3	1403.5
	Center line	-	1404.0
	Right wall	1402.2	1402.5
17+58.79	Left wall	1399.7	1400.2
	Center line	-	1400.9
	Right wall	1399.5	1400.5
16+83.79	Left wall	1386.9	1386.6
	Center line	-	1387.4
	Right wall	1386.7	1387.7
16+33.79	Left wall	1376.4	1376.1
	Center line	-	1376.2
	Right wall	1376.2	1376.8

(Sheet 1 of 3)

Note: Data plotted in Plates 5-7.
Q_C is chute discharge; Q_R is Big Sioux River discharge.

Table 1 (Continued)

Sta	Location	1969 Flood High-Water Mark	WES Physical 1:30 Model
15+83.79	Left wall	1366.2	1366.5
	Center line	-	1366.2
	Right wall	1366.0	1366.7
14+83.79	Left wall	1346.4	1346.9
	Center line	-	1346.7
	Right wall	1346.1	1346.4
14+33.79	Left wall	1336.4	1336.9
	Center line	-	1336.9
	Right wall	1336.3	1336.4
13+83.79	Left wall	1327.0	1327.3
	Center line	-	1327.1
	Right wall	1326.9	1327.1
13+50	Left wall	-	1320.3
	Center line	-	1319.8
	Right wall	-	1320.8
13+00	Left wall	-	1310.7
	Center line	-	1310.7
	Right wall	-	1310.2
12+50	Left wall	-	1308.0
	Center line	-	1305.8
	Right wall	-	1308.3
12+00	Left wall	-	1313.2
	Center line	-	1313.6
	Right wall	-	1313.8
11+50	Left wall	-	1328.7
	Center line	-	1327.8
	Right wall	-	1327.9

(Sheet 2 of 3)

Table 1 (Concluded)

Sta	Location	1969 Flood High-Water Mark	WES Physical 1:30 Model
11+17	Left wall	-	1324.4
	Center line	-	1325.1
	Right wall	-	1324.5

(Sheet 3 of 3)

Table 2
Water-Surface Profile Elevations, Existing Conditions, Q_C = 356 cu m/sec (12,700 cfs) Q_R = 6 cu m/sec (200 cfs), Tailwater El 1315.0

Sta	Water-Surface Elevations		
	Left Wall	Center Line	Right Wall
11+50	1317.6	1317.4	1317.1
12+00	1307.2	1307.8	1307.8
12+50	1301.4	1300.2	1299.7
13+00	1308.5	1308.8	1308.7
13+50	1318.6	1318.8	1318.4
14+00	1328.3	1328.3	1328.2
14+50	1338.0	1338.3	1337.9
15+00	1347.4	1347.1	1347.3
15+50	1357.5	1357.2	1357.8
16+00	1367.2	1366.6	1367.1
16+50	1376.9	1376.7	1376.9
17+00	1386.7	1387.8	1387.3
17+50	1395.3	1396.2	1395.9
18+00	1401.3	1401.7	1401.3
18+50	1406.6	1406.5	1406.4
19+00	1415.4	1415.3	1415.0
19+50	-	1417.8	-
20+00	-	1417.9	-
20+50	-	1418.0	-
21+00	-	1418.4	-
21+50	-	1418.2	-
22+00	1417.1	1417.1	1417.5
22+50	1416.5	1417.1	1416.5

Note: Data plotted in Plate 8.
Q_C is chute discharge; Q_R is Big Sioux River discharge.

Table 3
Water-Surface Profile Elevations, Existing Conditions,
Q_C = 591 cu m/sec (21,100 cfs), Q_R = 174 cu m/sec (6,200 cfs),
Tailwater El 1320.2

Sta	Water-Surface Elevations		
	Left Wall	Center Line	Right Wall
11+50	1323.9	1323.2	1322.3
12+00	1308.1	1307.8	1308.1
12+50	1300.5	1300.5	1300.4
13+00	1309.6	1309.9	1310.2
13+50	1320.0	1319.7	1320.1
14+00	1329.8	1329.8	1329.6
14+50	1339.4	1341.4	1340.0
15+00	1349.5	1349.8	1349.5
15+50	1358.7	1358.9	1358.6
16+00	1369.6	1369.0	1369.0
16+50	1379.3	1378.9	1379.0
17+00	1389.6	1390.1	1389.6
17+50	1399.4	1398.7	1399.6
18+00	1404.8	1405.1	1404.5
18+50	1410.1	1409.8	1409.6
19+00	-	1418.4	-
19+50	1421.5	1420.9	1421.0
20+00	1421.2	1421.3	1421.4
20+50	1421.3	1421.3	1421.2
21+00	1421.6	1421.6	1421.5
21+50	1421.6	1421.5	1421.6
22+00	1421.0	1421.4	1421.5
22+50	1420.5	1421.4	1420.5

Note: Data plotted In Plate 9.
Q_C is chute discharge; Q_R is Big Sioux River discharge.

Table 4
Water-Surface Profile Elevations, Existing Design,
Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs),
Tailwater El 1324.5

Sta	Water-Surface Elevations		
	Left Wall	Center Line	Right Wall
11+50	1331.2	1326.3	1328.4
12+00	1303.5	1300.7	1300.6
12+50	1301.9	1301.5	1301.5
13+00	1311.4	1311.2	1311.2
13+50	1 321.1	1322.0	1321.7
14+00	1331.3	1331.5	1331.4
14+50	1341.5	1341.7	1 341.2
15+00	1350.9	1351.0	1350.5
15+50	1361.3	1360.7	1360.8
16+00	1371.3	1370.3	1371.0
16+50	1381.5	1381.0	1380.9
17+00	1392.4	1392.5	1392.2
17+50	1401.8	1401.9	1401.9
18+00	1407.6	1407.7	1407.7
18+50	1412.9	1412.4	1412.7
19+50	1424.6	1424.2	1424.7
20+00	1423.3	1422.4	1424.8
20+50	1424.8	1424.7	1424.8
21+00	1425.2	1425.0	1425.0
21+50	1425.1	1425.0	1424.9
22+00	1424.6	1424.5	1424.5
22+50	1423.5	1423.9	1422.7

Note: Data plotted in Plate 10.
Q_C is chute discharge; Q_R is Big Sioux River discharge.

Table 5
Water-Surface Profile Elevations, Existing Conditions, Q_C = 1,044 cu m/sec (37,300 cfs), Q_R = 812 cu m/sec (29,000 cfs), Tailwater El 1327.0

Sta	Water-Surface Elevations		
	Left Wall	Center Line	Right Wall
End sill	1337.0	1336.4	1332.5
11+50	1339.2	1338.6	1337.3
12+00	1313.0	1312.1	1311.2
12+50	1304.7	1304.6	1304.7
13+00	1314.5	1313.8	1314.5
13+50	1324.0	1322.7	1323.1
14+00	1332.7	1332.5	1333.0
14+50	1342.8	1342.9	1342.9
15+00	1352.5	1352.8	1352.6
15+50	1362.8	1362.7	1362.7
16+00	1374.3	1373.6	1373.9
16+50	1384.9	1384.1	1384.3
17+00	1398.9	1399.1	1398.4
17+50	1406.0	1406.2	1406.0
18+00	1410.7	1411.9	1411.4
18+50	1416.5	1416.5	1416.3
19+00	1425.6	1425.3	1425.6
19+50	1429.0	1428.6	1428.7
20+00	1429.7	1429.9	1429.6

Note: Data plotted in Plate 11.
Q_C is chute discharge; Q_R is Sioux River Discharge.

Table 6
Velocities, Existing Conditions, Q_C = 812 cu m/sec (29,000 cfs), Q_R = 168 cu m/sec (6,000 cfs), Tailwater El 1322.0

Distance from Center Line[1]	Surface Velocity[2]	Direction of Flow[3]	Middepth Velocity[2]	Direction of Flow[3]	Bottom Velocity[2]	Direction of Flow[3]
			Sta 12+12			
21 Left	-	-	-	-	29.7	1:00
CL	-	-	-	-	14.1	1:00
21 Right	-	-	-	-	30.6	1:00
			End Sill (0+00A)			
25 Left	14.3	12:00T	14.9	12:00T	9.2	12:00T
CL	19.2	12:00T	21.1	12:00T	8.6	12:00T
25 Right	18.0	12:00T	10.7	12:00T	5.5	12:00T
			200 ft Downstream of End Sill (2+00A)			
50 Left	18.2	11:00T	14.3	11:00T	12.4	11:00
CL	16.8	12:00T	10.2	11:00T	5.4	11:00T
50 Right	9.2	12:00	4.9	12:00T	3.1	9:30
			250 ft Downstream of End Sill (2+50A)			
75 Left	15.2	11:00	12.0	11:00	6.2	11:00
25 Left	15.6	12:00	9.9	11:00T	7.4	11:00T
			300 ft Downstream of End Sill (3+00A)			
100 Left	15.1	11:30	10.5	11:30	5.9	11:00
50 Left	13.2	11:30	9.6	11:30T	6.0	11:00
25 Left	12.7	11:30	5.7	11:00T	3.6	9:30T

Note: Data plotted in Plates 12-14.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1] Distances given in feet. To convert to meters multiply by 0.3048.
[2] Velocities given in fps. To convert to m/sec multiply by 0.3048.
[3] 12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 7
Velocities, Existing Conditions, Q_C = 812 cu m/sec (29,000 cfs), Q_R = 224 cu m/sec (8,000 cfs), Tailwater El 1322.5

Distance from Center Line[1]	Surface Velocity[2]	Direction of Flow[3]	Middepth Velocity[2]	Direction of Flow[3]	Bottom Velocity[2]	Direction of Flow[3]
Sta 12+25.5						
21 Left	-	-	-	-	45.1	12:00T
CL	-	-	-	-	32.2	12:00T
21 Right	-	-	-	-	30.4	12:00T
End Sill (0+00A)						
25 Left	16.9	12:00T	12.3	12:00T	7.2	12:00T
CL	16.4	12:00T	2.7	12:00T	6.8	12:00T
25 Right	15.2	12:00T	1.2	12:00T	2.8	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	19.1	11:30	11.5	11:30	9.4	12:00
CL	13.8	11:30	7.5	11:00T	6.0	11:00T
50 Right	6.8	12:00T	4.4	12:00T	2.9	12:00T
250 ft Downstream of End Sill (2+50A)						
75 Left	16.5	11:00	11.2	11:00	5.8	11:00T
25Left	15.1	11:30	8.2	11:30	5.7	11:00T
300 ft Downstream of End Sill (3+00A)						
100 Left	14.7	11:00	11.5	11:00	6.1	11:00
50 Left	15.2	11:00	9.3	11:00	5.6	11:00T
25 Left	12.9	11:30	5.8	11:30	3.9	9:30T

Note: Data plotted in Plates 15-17.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1] Distances given in feet. To convert to meters multiply by 0.3048.
[2] Velocities given in fps. To convert to m/sec multiply by 0.3048.
[3] 12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 8
Velocities, Existing Conditions, Q_C = 812 cu m/sec (29,000 cfs), Q_R = 280 cu m/sec (10,000 cfs), Tailwater El 1322.8

Distance from Center Line [1]	Surface Velocity [2]	Direction of Flow [3]	Middepth Velocity [2]	Direction of Flow [3]	Bottom Velocity [2]	Direction of Flow [3]
Sta 12+40						
21 Left	-	-	-	-	54.5	10:00
CL	-	-	-	-	55.3	11:00
21 Right	-	-	-	-	62.3	11:00
End Sill (0+00A)						
25 Left	16.4	12:00T	12.5	12:00T	6.1	12:00T
CL	15.7	12:00T	22.6	12:00T	6.6	12:00T
25 Right	14.8	12:00T	11.2	12:00T	3.4	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	18.9	11:00	13.3	11:00	11.9	11:00
CL	16.3	12:00	7.3	11:00T	6.7	11:00T
50 Right	8.9	12:00	4.7	12:00T	4.5	9:30T
250 ft Downstream of End Sill (2+50A)						
75 Left	14.7	11:00	11.9	11:00	8.8	11:00
25 Left	13.0	12:00	8.0	11:30	7.2	11:00
300 ft Downstream of End Sill (3+00A)						
100 Left	14.3	11:00	11.1	11:00	7.6	11:00
50 Left	14.2	11:30	9.3	11:30T	5.1	11:00T
25 Left	11.1	12:00	6.0	11:00	4.1	9:30T

Note: Data plotted in Plates 18-20.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1] Distances given in feet. To convert to meters multiply by 0.3048.
[2] Velocities given in fps. To convert to m/sec multiply by 0.3048.
[3] 12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 9
Velocities, Existing Conditions, Q_C = 812 cu m/sec (29,000 cfs), Q_R = 336 cu m/sec (12,000 cfs), Tailwater El 1323.1

Distance from Center Line[1]	Surface Velocity[2]	Direction of Flow[3]	Middepth Velocity[2]	Direction of Flow[3]	Bottom Velocity[2]	Direction of Flow[3]
Sta 12+40						
21 Left	-	-	-	-	37.5	12:00T
CL	-	-	-	-	40.8	12:00
21 Right	-	-	-	-	45.1	12:00e
E nd Sill (0+00A)						
25 Left	17.8	12:00T	12.5	12:00T	5.9	12:00T
CL	16.2	12:00T	23.2	12:00T	6.4	12:00T
25 Right	15.6	12:00T	9.2	12:00T	2.8	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	18.6	11:30	13.9	11:00	11.5	11:00
CL	17.0	12:00T	7.5	10-11T	4.7	11:00T
50 Right	8.6	11-12T	5.5	10:30	3.8	9:00
250 ft Downstream of End Sill (2+50A)						
75 Left	16.6	11:30	11.1	11:30	6.2	11:00T
25 Left	15.0	11:00	9.3	11:00	6.1	11:00T
300 ft Downstream of End Sill (3+00A)						
100 Left	14.8	11:00	11.3	11:00	6.2	11:00
50 Left	13.8	11:00	10.1	11:00	5.5	11:00
25 Left	13.0	11:30	5 .9	11:30	5.4	9:30

Note: Data plotted in Plates 21-23.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1] Distances given in feet. To convert to meters multiply by 0.3048.
[2] Velocities given in fps. To convert to m/sec multiply by 0.3048.
[3] 12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 10
d_1, v_1, d_2, v_2, Existing Channel Configuration, Type 1 Stilling Basin, Q_c = 812 cu m/sec (29,000 cfs)

Location of Measurement	Q_R = 168 cu m/sec (6,000 cfs) Tailwater El 1322.0			
	Sta 12+12		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Left Wall	15.1	29.7	28.4	14.3 (s) 14.9 (m) 9.2 (b)
Center Line	14.7	14.1	30.4	19.2 (s) 21.1 (m) 8.6 (b)
Right Wall	15.9	30.6	29.4	18.0 (s) 10.7 (m) 5.5 (b)
Location of Measurement	Q_R = 224 cu m/sec (8,000 cfs) Tailwater El 1322.5			
	Sta 12+25.5		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Left Wall	12.8	45.1	28.7	16.9 (s) 12.3 (m) 7.2 (b)
Center Line	18.0	32.2	30.4	16.4 (s) 22.7 (m) 6.8 (b)
Right Wall	15.3	30.4	29.8	15.2 (s) 11.2 (m) 2.8 (b)

(Continued)

Note: Data plotted in Plates 28-31.
d_1 = tailwater depth entering stilling basin; d_2 = hydraulic jump secant depth.
v_1 = velocity entering stilling basin; v_2 = velocity at hydraulic jump secant depth.
s = surface, m = middepth, b = bottom.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.

Table 10 (Concluded)

Location of Measurement	Q_R = 280 cu m/sec (10,000 cfs) Tailwater El 1322.8			
	Sta 12+40		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Left Wall	9.9	54.5	29.7	16.4 (s) 12.5 (m) 6.1 (b)
Center Line	9.7	55.3	31.7	15.7 (s) 22.6 (m) 6.6 (b)
Right Wall	10.6	62.3	30.5	14.8 (s) 11.2 (m) 3.4 (b)
Location of Measurement	**Q_R = 336 cu m/sec (12,000 cfs) Tailwater El 1323.1**			
	Sta 12+40		**End Sill**	
	d_1, ft[1]	**v_1, fps[2]**	**d_2, ft[1]**	**v_2, fps[2]**
Left Wall	10.4	37.5	29.7	17.8 (s) 12.5 (m) 5.9 (b)
Center Line	10.0	40.8	31.7	16.2 (s) 23.2 (m) 6.4 (b)
Right Wall	10.3	45.1	30.5	15.6 (s) 9.2 (m) 2.8 (b)

Table 11
Flood Event Discharges

Flood Event	Q_C		Q_R		Tailwater El
	cu m/sec	cfs	cu m/sec	cfs	
10-year	356	12,700	6	200	1315.0
50-year	591	21,100	174	6,200	1320.2
1969	812	29,000	317	11,300	1324.5
100-year	812	29,000	204	7,300	1322.5
500-year	1,044	37,300	812	29,000	1327.0

Table 12
Discharges and Tailwater Elevations for d_1 and d_2 Measurements

Q_C		Q_R		Tailwater, El	Table
cu m/sec	cfs	cu m/sec	cfs		
356	12,700	6	200	1315	
591	21,100	174	6,200	1318, 1324	31
700	25,000	224	8,000	1320, 1326	31, 41
812	29,000	168	6,000	1322	10
812	29,000	204	7,300	1322, 1322.5, 1328	31, 41
812	29,000	224	8,000	1322.5	10
812	29,000	280	10,000	1322.8	10
812	29,000	336	12,000	1323.1	10
1,044	37,300	812	29,000	1326, 1327, 1330	31, 41

Note: d_1 = tailwater depth entering stilling basin; d_2 = hydraulic jump secant depth.

Table 13
Water-Surface Elevations, Existing Channel Configuration, Q_C = 356 cu m/sec (12,700 cfs), Q_R = 6 cu m/sec (200 cfs)

Sta	Distance from Center Line, ft[1]	Tailwater El 1315.0
12+50	21 Left	1302.9
	CL	1302.1
	21 Right	1302.0
12+00	21 Left	1309.2
	CL	1310.6
	21 Right	1310.7
11+50	21 Left	1317.5
	CL	1317.7
	21 Right	1316.8
End sill	92 Left[2]	1315.5
	50 Left	1315.3
	25 Left	1316.6
	CL	1316.3
	25 Right	1316.3
	50 Right	1315.6
1+00A	100 Left[2]	1316.2
	75 Left	1316.1
	50 Left	1316.0
	25 Left	1316.1
	CL	1315.8
	25 Right	1316.1
	50 Right	1316.1
2+00A	117 Left[2]	1315.3
	75 Left	1315.4
	50 Left	1315.4

(Continued)

Note: Data plotted in Plate 32
Q_C is chute discharge; Q_R is Big Sioux River discharge
[1]To convert from ft to m multiply by 0.3048.
[2] Water's edge.

Table 13 (Concluded)

Sta	Distance from Center Line, ft[1]	Tailwater El 1315.0
2+50A	155 Left[2]	1315.0
	125 Left	1315.1
	75 Left	1315.3
	25 Left	1315.6
	CL	1316.0
	25 Right	1316.0
	75 Right	1315.6
3+00A	185 Left[2]	1315.1
	175 Left	1315.1
	150 Left	1315.2
	100 Left	1315.3
	50 Left	1315.5
	25 Left	1315.8
	CL	1316.1
	25 Right	1316.5
	50 Right	1316.3
	75 Right	1315.7
3+50A	225 Left[2]	1315.0
	200 Left	1315.0
	175 Left	1315.2
	125 Left	1315.0
	75 Left	1315.4
	50 Left	1316.6
4+50A	260 Left[2]	1314.9
	225 Left	1315.0
	175 Left	1315.0
	125 Left	1315.0
	100 Left	1315.1
	75 Left	1315.2

Table 14
Water-Surface Elevations, Existing Channel Configuration, Q_C = 591 cu m/sec (21,100 cfs), Q_R = 174 cu m/sec (6,200 cfs)

Sta	Distance from Center Line, ft[1]	Tailwater El 1318.0	Tailwater El 1320.2	Tailwater El 1324.0
12+64	21 Left	-	-	1307.6
	CL	-	-	1307.2
	21 Right	-	-	1307.8
12+50	21 Left	1301.3	1301.2	-
	CL	1300.7	1300.1	-
	21 Right	1301.1	1300.5	-
12+00	21 Left	-	1309.0	-
	CL	-	1308.3	-
	21 Right	-	1308.8	-
11+50	21 Left	-	1323.6	-
	CL	-	1323.0	-
	21 Right	-	1322.6	-
End sill	107 Left[2]	-	1321.9	-
	75 Left	-	1321.1	-
	50 Left	-	1321.3	-
	25 Left	1322.0	1322.5	1326.4
	CL	1321.6	1323.0	1326.3
	25 Right	1321.8	1322.7	1326.6
	50 Right	-	1321.9	-
1+00A	119 Left[2]	-	1322.3	-
	100 Left	-	1321.9	-
	75 Left	-	1321.9	-
	50 Left	-	1322.2	-
	25 Left	-	1322.2	-
	CL	-	1322.3	-
	25 Right	-	1322.4	-
	50 Right	-	1322.3	-

(Sheet 1 of 3)

Note: Data plotted in Plates 33-35.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2] Water's edge.

Table 14 (Continued)				
Sta	**Distance from Center Line, ft[1]**	**Tailwater El 1318.0**	**Tailwater El 1320.2**	**Tailwater El 1324.0**
2+00A	139 Left[2]	-	1320.7	-
	125 Left	-	1320.7	-
	100 Left	-	1320.7	-
	50 Left	1320.1	1320.8	1323.9
	CL	1319.8	1321.3	1324.0
	50 Right	1319.4	1321.3	1324.2
2+50A	172 Left[2]	-	1320.5	-
	150 Left	-	1320.5	-
	125 Left	-	1320.5	-
	75 Left	1319.2	1321.0	1324.0
	25 Left	1319.2	1321.2	1324.1
	CL	-	-	-
	25 Right	-	1321.4	1324.1
	75 Right	-	1321.4	-
3+00A	204 Left[2]	-	1320.6	-
	175 Left	-	1320.7	-
	150 Left	-	1320.8	-
	100 Left	1319.1	1321.0	1324.2
	50 Left	1319.4	1321.0	1324.2
	25 Left	1319.5	1321.3	1324.2
	CL	-	1321.5	-
	25 Right	-	1321.5	1324.7
	75 Right	-	1321.5	-
3+50A	242 Left[2]	-	1321.3	-
	200 Left	-	1321.2	-
	175 Left	-	1320.9	-
	125 Left	-	1320.7	-
	75 Left	-	1320.7	-
	50 Left	-	1320.5	-

(Sheet 2 of 3)

Table 14 (Concluded)

Sta	Distance from Center Line, ft[1]	Tailwater El 1318.0	Tailwater El 1320.2	Tailwater El 1324.0
4+50A	305 Left[2]	-	1320.5	-
	250 Left	-	1320.5	-
	225 Left	-	1320.5	-
	175 Left	-	1320.5	-
	125 Left	-	1320.5	-
	100 Left	-	1320.1	-
5+00A	329 Left[2]	-	1320.5	-
	317 Left	-	1320.6	-
	300 Left	-	1320.5	-
	225 Left	-	1320.5	-
	175 Left	-	1320.1	-
	125 Left	-	1320.1	-
5+50A	300 Left[2]	-	1320.7	-
	225 Left	-	1320.5	-
	175 Left	-	1320.5	-
	125 Left	-	1320.2	-

(Sheet 3 of 3)

Table 15
Water-Surface Elevations, Existing Channel Configuration, Q_C = 700 cu m/sec (25,000 cfs), Q_R = 224 cu m/sec (8,000 cfs)

Sta	Distance from Center Line, ft[1]	Tailwater El 1320.0	Tailwater El 1326.0
12+36.5	21 Left	1298.3	-
	CL	1298.2	-
	21 Right	1298.3	-
12+50	21 Left	-	1302.9
	CL	-	1303.6
	21 Right	-	1304.0
End sill	25 Left	1323.9	1328.2
	CL	1324.3	1329.1
	25 Right	1323.5	1328.9
2+00A	50 Left	1320.6	1326.1
	CL	1321.0	1326.0
	50 Right	1321.1	1325.9
2+50A	75 Left	1321.0	1325.8
	25 Left	1321.0	1326.1
3+00A	100 Left	1320.8	1325.9
	50 Left	1321.0	1325.8
	25 Left	1321.2	1326.1

Note: Data plotted in Plates 36 and 37

Q_C = chute discharge; Q_R = Big Sioux River discharge

[1]To convert ft to m multiply by 0.3048

Table 16
Water-Surface Elevations, Existing Channel Configuration, Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs)

Sta	Distance from Center Line, ft[1]	Tailwater El 1322.0	Tailwater El 1322.5	Tailwater El 1328.0
12+56	21 Left	-	-	1306.1
	CL	-	-	1304.8
	21 Right	-	-	1305.8
12+35	21 Left	1301.5	1301.6	-
	CL	1301.4	1302.0	-
	21 Right	1301.3	1301.7	-
12+00	21 Left	-	1303.3	-
	CL	-	1303.6	-
	21 Right	-	1303.9	-
11+50	21 Left	-	1328.9	-
	CL	-	1329.6	-
	21 Right	-	1329.2	-
End sill	111 Left[2]	-	1322.8	-
	75 Left	-	1322.6	-
	50 Left	-	1322.6	-
	25 Left	1323.8	1323.6	1329.1
	CL	1324.5	1324.9	1331.1
	25 Right	1323.4	1324.1	1330.7
	50 Right	-	1323.6	-
	75 Right	-	1323.7	-
1+00A	122 Left[2]	-	1323.6	-
	100 Left	-	1323.4	-
	75 Left	-	1323.4	-
	50 Left	-	1323.6	-
	25 Left	-	1323.4	-
	CL	-	1323.3	-
	25 Right	-	1324.0	-
	50 Right	-	1324.1	-

(Sheet 1 of 3)

Note: Data plotted in Plates 38-40.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert ft to m, multiply by 0.3048
[2] Water's edge.

Table 16 (Continued)

Sta	Distance from Center Line, ft[1]	Tailwater El 1322.0	Tailwater El 1322.5	Tailwater El 1328.0
1+00A (Cont)	75 Right	-	1324.3	-
2+00A	148 Left[2]	-	1322.8	-
	125 Left	-	1322.8	-
	100 Left	-	1322.2	-
	50 Left	1322.8	1323.3	1327.7
	CL	1322.6	1322.9	1327.9
	50 Right	1322.5	1323.0	1327.6
2+50A	178 Left[2]	-	1321.9	-
	175 Left	-	1321.9	-
	150 Left	-	1321.9	-
	125 Left	-	1322.2	-
	75 Left	1323.4	1323.2	1328.0
	25 Left	1322.5	1323.0	1328.0
	25 Right	-	1323.1	-
	75 Right	-	1323.0	-
3+00A	208 Left[2]	-	1322.0	-
	200 Left	-	1322.2	-
	175 Left	-	1322.2	-
	150 Left	-	1322.3	-
	100 Left	1322.7	1323.0	1327.8
	50 Left	1322.7	1323.2	1328.1
	25 Left	1323.3	1323.3	1328.0
	CL	-	1323.7	-
	25 Right	-	1323.7	-
	75 Right	-	1323.5	-

(Sheet 2 of 3)

Table 16 (Concluded)

Sta	Distance from Center Line, ft[1]	Tailwater El 1322.0	Tailwater El 1322.5	Tailwater El 1328.0
3+50A	250 Left[2]	-	1322.1	-
	200 Left	-	1322.1	-
	175 Left	-	1322.1	-
	125 Left	-	1322.4	-
	75 Left	-	1323.1	-
	50 Left	-	1323.3	-
4+50A	312 Left[2]	-	1321.9	-
	250 Left	-	1322.2	-
	225 Left	-	1322.2	-
	175 Left	-	1322.2	-
	125 Left	-	1322.0	-
	100 Left	-	1322.0	-
5+00A	346 Left[2]	-	1323.3	-
	318 Left	-	1323.3	-
	300 Left	-	1323.5	-
	225 Left	-	1322.1	-
	175 Left	-	1322.2	-
	125 Left	-	1322.2	-
	100 Left	-	1322.2	-
5+50A	375 Left[2]	-	1322.1	-
	318 Left	-	1322.1	-
	300 Left	-	1322.2	-
	250 Left	-	1322.6	-
	225 Left	-	1322.4	-
	175 Left	-	1322.3	-
	125 Left	-	1322.5	-

(Sheet 3 of 3)

Table 17
Water-Surface Elevations, Existing Channel Configuration, Q_C = 1,044 cu m/sec (37,300 cfs) Q_R = 812 cu m/sec (29,000 cfs)

Sta	Distance from Center Line, ft[1]	Tailwater El 1326.0	Tailwater El 1327.0	Tailwater El 1330.0
12+50	21 Left	-	-	1303.9
	CL	-	-	1303.4
	21 Right	-	-	1303.3
12+35	21 Left	1305.0	1300.6	-
	CL	1305.2	1300.6	-
	21 Right	1305.3	1300.3	-
12+00	21 Left	-	1304.0	-
	CL	-	1305.3	-
	21 Right	-	1306.3	-
11+50	21 Left	-	1339.2	-
	CL	-	1338.6	-
	21 Right	-	1337.3	-
End sill	100 Left[2]	-	1328.0	-
	75 Left	-	1327.9	-
	50 Left	-	1327.9	-
	25 Left	1333.7	1337.0	1336.5
	CL	1336.5	1336.4	1336.2
	25 Right	1337.2	1332.5	1335.2
	50 Right	-	1329.6	-
	75 Right	-	1329.4	-
	100 Right	-	1326.6	-
1+00A	125 Left[2]	-	1328.9	-
	100 Left	-	1328.9	-
	75 Left	-	1328.9	-
	50 Left	-	1328.6	-
	25 Left	-	1329.8	-

(Sheet 1 of 3)

Note: Data plotted in Plates 41-43.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m, multiply by 0.3048.
[2] Water's edge.

Table 17 (Continued)

Sta	Distance from Center Line, ft[1]	Tailwater El 1326.0	Tailwater El 1327.0	Tailwater El 1330.0
1+00A (Continued)	CL	-	1331.4	-
	25 Right	-	1329.4	-
	50 Right	-	1329.4	-
	75 Right	-	1329.9	-
2+00A	150 Left[2]	-	1327.3	-
	125 Left	-	1327.7	-
	100 Left	-	1327.4	-
	50 Left	1326.5	1327.4	1328.6
	CL	1327.2	1327.7	1329.4
	50 Right	1328.5	1328.4	1329.9
	100 Right	-	1329.8	-
2+50A	175 Left	-	1327.2	-
	150 Left	-	1327.6	-
	125 Left	-	1327.6	-
	75 Left	1325.5	1327.9	1329.5
	25 Left	1327.3	1328.6	1329.7
	25 Right	-	1328.7	-
	75 Right	-	1329.1	-
3+00A	200 Left[2]	-	1327.2	-
	175 Left	-	1327.2	-
	150 Left	-	1327.5	-
	100 Left	1327.1	1327.8	1329.7
	50 Left	1327.8	1327.3	1329.8
	25 Left	1327.5	1327.5	1329.8
	CL	-	1328.4	-
	25 Right	-	1328.4	-
	75 Right	-	1329.0	-

(Sheet 2 of 3)

Table 17 (Concluded)

Sta	Distance from Center Line, ft[1]	Tailwater El 1326.0	Tailwater El 1327.0	Tailwater El 1330.0
3+50A	250 Left[2]	-	1327.1	-
	200 Left	-	1327.1	-
	175 Left	-	1327.1	-
	125 Left	-	1327.3	-
	75 Left	-	1327.4	-
	50 Left	-	1327.9	-
4+50A	300 Left[2]	-	1326.9	-
	250 Left	-	1326.7	-
	225 Left	-	1326.4	-
	175 Left	-	1326.4	-
	125 Left	-	1326.4	-
	100 Left	-	1326.4	-
	50 Left	-	1327.5	-
5+00A	300 Left	-	1326.8	-
	250 Left	-	1326.8	-
	225 Left	-	1326.7	-
	175 Left	-	1326.1	-
	125 Left	-	1326.2	-
	100 Left	-	1326.2	-
5+50A	300 Left	-	1326.8	-
	250 Left	-	1326.8	-
	225 Left	-	1326.8	-
	175 Left	-	1326.8	-
	125 Left	-	1326.4	-

(Sheet 3 of 3)

Table 18
Velocities, Existing Design, Q_C = 356 cu m/sec (12,700 cfs), Tailwater El 1315.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+50						
21 Left	-	-	-	-	5.0	12:00
CL	-	-	-	-	6.0	12:00
21 Right	-	-	-	-	6.1	12:00
Sta 12+00						
21 Left	9.1	12:00	9.3	12:00	3.7	12:00
CL	9.6	12:00	8.8	12:00	22.4	12:00
21 Right	9.0	12:00	10.7	12:00	30.5	12:00
Sta 11+50						
21 Left	10.0	12:00	8.5	12:00	4.8	12:00
CL	9.2	12:00	8.2	12:00	6.4	12:00
21 Right	8.8	12:00	5.0	12:00	3.9	12:00
End Sill (0+00A)						
75 Left	-	-	2.1	12:00T	2.1	12:00
50 Left	1.5	12:00	1.3	12:00	2.6	12:00T
25 Left	13.7	12:00	9.3	12:00	6.5	12:00
CL	10.0	12:00	10.3	12:00	3.1	12:00
25 Right	10.5	12:00	7.2	12:00	5.0	12:00
50 Right	2.1	12:00	2.1	12:00	1.7	12:00
75 Right	2.1	12:00	2.1	12:00	2.1	12:00
100 ft Downstream of End Sill (1+00A)						
75 Left	3.2	11:00T	3.2	11:00T	2.7	12:00T
50 Left	10.0	11:30T	7.5	11:30T	5.8	12:00T
25 Left	10.8	12:00	6.7	12:00	5.3	12:00
CL	11.7	12:00	9.1	12:00	6.9	12:00
25 Right	11.0	12:00	8.3	12:00	6.5	12:00

(Continued)

Note: Data plotted in Plates 44-46.
Q_C = chute discharge; Q_R = Big Sioux River discharge
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 18 (Concluded)						
Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
100 ft Downstream of End Sill (1+00A) (continued)						
50 Right	4.7	12:00	3.4	11:30	3.0	12:00
75 Right	2.1	11:30	2.1	11:30	2.1	11:30
200 ft Downstream of End Sill (2+00A)						
75 Left	8.2	12:00	7.7	12:00	5.8	12:00
50 Left	9.2	12:00	8.3	12:00	7.0	12:00
CL	8.7	11:30	7.4	11:30	6.6	11:30
50 Right	4.4	12:00T	3.3	12:00T	2.5	12:00T
250 ft Downstream of End Sill (2+50A)						
125 Left	2.6	5:00	2.6	5:00	2.6	5:00
75 Left	8.5	11:30	7.3	11:30	5.0	11:00T
25 Left	9.0	11:30T	8.0	11:30T	8.0	11:00
CL	7.4	12:00	6.5	12:00	4.9	12:00
25 Right	5.8	12:00	4.4	12:00	3.1	12:00
75 Right	3.5	2:00	3.5	2:30	4.1	3:00
300 ft Downstream of End Sill (3+00A)						
150 Left	2.1	11:00	2.1	11:00	2.1	10:00
100 Left	7.4	10:00	7.0	10:00	6.5	10:00
50 Left	7.5	10:00	7.2	10:00	6.3	10:00
25 Left	8.0	11:00	6.3	10:00T	5.4	10:00
CL	5.3	10:00	4.2	10:00	2.7	9:00T
25 Right	2.4	3:30	-	-	2.5	3:30
50 Right	4.3	3:00T	-	-	-	-
350 ft Downstream of End Sill (3+50A)						
175 Left	3.4	10:00	4.9	10:00	4.7	10:00
125 Left	7.8	10:00	8.1	10:00	6.8	10:00
75 Left	8.5	10:00	8.3	10:00	6.5	10:00
50 Left	8.3	10:00	7.9	10:00	6.7	10:00
450 ft Downstream of End Sill (4+50A)						
225 Left	3.8	11:30	4.0	11:30	3.3	11:30
175 Left	6.0	10:30	7.6	10:30	6.2	10:30
125 Left	8.5	10:00	9.0	10:00	8.5	10:00
100 Left	9.6	10:00	10.0	10:00	8.6	10:00

Table 19
Velocities, Existing Channel Configuration, Q_C = 591 cu m/sec (21,100 cfs), Q_R = 174 cu m/sec (6,200 cfs), Tailwater El 1318.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+50						
21 Left	-	-	-	-	18.9	12:00
CL	-	-	-	-	19.7	12:00
21 Right	-	-	-	-	22.6	12:00
End Sill (0+00A)						
25 Left	14.6	12:00	12.4	12:00	7.1	12:00
CL	14.9	12:00	16.6	12:00	4.1	12:00
25 Right	13.1	12:00	9.9	12:00	4.7	12:00
200 ft Downstream of End Sill (2+00A)						
50 Left	15.1	11:30	11.7	11:30	11.7	11:30
CL	12.8	12:00	5.4	12:00	5.4	11:30
50 Right	6.5	12:00	2.4	12:00	3.1	10:00
250 ft Downstream of End Sill (2+50A)						
75 Left	13.7	11:30	9.8	11:30	7.6	11:00
25 Left	13.1	11:30	8.8	11:30	7.1	11:30
300 ft Downstream of End Sill (3+00A)						
100 Left	12.1	11:30	10.6	11:30	7.8	11:00
50 Left	12.5	11:30	8.4	11:30	5.5	11:30
25 Left	9.9	10-11T	6.7	11:00	5.8	10:00

Note: Data plotted in Plates 47-49.
Q_C = chute discharge; Q_R = Big Sioux River discharge
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 20
Velocities, Existing Design, Q_C = 591 cu m/sec (21,100 cfs), Q_R = 174 cu m/sec (6,200 cfs), Tailwater El 1320.2

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+50						
21 Left	-	-	-	-	15.9	12:00
CL	-	-	-	-	16.1	12:00
21 Right	-	-	-	-	15.7	12:00
Sta 12+00						
21 Left	10.4	12:00T	14.3	12:00T	27.1	12:00
CL	10.9	12:00T	14.9	12:00T	11.3	12:00T
21 Right	9.4	12:00T	10.0	12:00T	29.5	12:00
Sta 11+50						
21 Left	8.2	12:00T	10.3	12:00T	6.7	12:00T
CL	5.6	12:00T	5.8	12:00T	9.4	12:00T
21 Right	7.7	12:00T	10.2	12:00T	5.4	12:00T
End Sill (0+00A)						
50 Left	1.8	12:00	1.6	12:00	3.4	12:00
25 Left	14.4	12:00	13.0	12:00	6.1	12:00
CL	14.1	12:00	14.4	12:00	5.1	12:00
25 Right	11.8	12:00	9.6	12:00	4.6	12:00
100 ft Downstream of End Sill (1+00A)						
100 Left	-	-	-	-	2.1	12:00T
75 Left	7.0	11:30	5.9	11:00 T	5.3	12:00T
50 Left	14.4	12:00	7.0	11:30	5.8	11:30
25 Left	16.4	12:00	9.3	12:00	6.4	12:00
CL	15.7	12:00	8.8	12:00	5.9	12:00
25 Right	14.7	12:00	4.9	12:00	3.0	12:00
50 Right	7.3	12:00	3.1	11:00	2.7	11:00
75 Right	2.5	10:30	-	-	1.9	11:00

(Sheet 1 of 3)

Note: Data plotted in Plates 50-52.
Q_C = chute discharge; Q_R = Big Sioux River discharge
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 20 (Continued)						
Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[2]	Bottom Velocity fps	Direction of Flow[3]
200 ft Downstream of End Sill (2+00A)						
125 Left	-	-	-	-	2.4	12:00T
75 Left	11.1	11:00	11.0	11:00	9.8	11:00
50 Left	14.5	12:00	12.7	12:00	10.5	12:00
CL	14.1	11:00	7.8	12:00	5.9	11:00
50 Right	7.1	12:00	5.1	11:00	3.3	11:00
250 ft Downstream of End Sill (2+50A)						
150 Left	1.7	12:00T	-	-	1.6	12:00T
125 Left	8.9	11:00	6.8	11:00	5.1	11:00
75 Left	12.1	11:00	9.6	11:00	7.5	11:00
25 Left	12.7	11:00	8.2	11:00	7.1	11:00
25 Right	7.8	12:00	5.1	12:00	2.9	11:00
75 Right	1.2	3:00	-	-	1.2	3:00
300 ft Downstream of End Sill (3+00A)						
175 Left	2.3	11:00	-	11:00	2.5	11:00
150 Left	7.5	11:00	7.2	11:00	6.2	11:00
100 Left	11.7	11:00	9.4	11:00	6.0	11:00
50 Left	12.0	10:00	9.6	10:00T	5.4	10:00T
25 Left	10.0	11:30	6.0	11:30T	4.3	10:00T
CL	6.3	12:00T	3.4	12:00T	2.5	12:00T
25 Right	3.7	12:00T	2.1	12:00T	2.2	12:00T
350 ft Downstream of End Sill (3+50A)						
200 Left	5.4	10:30	6.0	10:30	6.0	10:30
175 Left	8.6	11:00	8.4	10:30	7.0	11:00
125 Left	11.6	11:00	9.8	11:00	6.0	11:00
75 Left	10.3	11:00	8.4	11:00	7.8	11:00
50 Left	9.4	11:00	9.1	11:00	8.1	11:00
						(Sheet 2 of 3)

Table 20 (Concluded)

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
450 ft Downstream of End Sill (4+50A)						
250 Left	7.3	11:00	7.6	11:00	6.0	11:00
225 Left	8.9	11:00	9.1	11:30	6.6	11:30
175 Left	10.9	10:30	10.7	10:30	9.0	10:30
125 Left	12.2	10:00	10.9	10:00	8.9	10:00
100 Left	-	-	-	-	5.0	10:00
500 ft Downstream of End Sill (5+00A)						
300 Left	4.9	11:00	5.6	11:00	4.6	11:00
225 Left	9.6	11:00	10.2	11:00	8.4	11:00
175 Left	11.6	11:00	11.0	11:00	8.9	11:00
125 Left	2.5	11:00	-	-	1.8	11:00
550 ft Downstream of End Sill (5+50A)						
325 Left	5.4	11:30	5.4	11:00	4.6	11:00
300 Left	6.9	11:00	7.7	11:00	6.6	11:00
225 Left	10.8	11:00	10.6	11:00	8.2	11:00
175 Left	9.7	11:00	8.3	11:00	6.3	11:00
125 Left	-	-	-	-	2.8	11:00

(Sheet 3 of 3)

Table 21
Velocities, Existing Channel Configuration, Q_C = 591 cu m/sec (21,100 cfs), Q_R = 174 cu m/sec (6,200 cfs), Tailwater El 1324.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+64						
21 Left	-	-	-	-	20.0	12:00
CL	-	-	-	-	17.4	12:00
21 Right	-	-	-	-	17.3	12:00
End Sill (0+00A)						
25 Left	15.3	12:00T	10.8	12:00T	4.6	12:00T
CL	16.1	12:00	11.1	12:00T	3.5	12:00T
25 Right	14.8	12:00T	7.9	12:00T	4.0	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	13.1	11:30	10.1	11:30	8.0	11:30
CL	11.5	12:00	4.6	11:30	1.7	11:30
50 Right	5.9	12:00	3.3	11:00	2.3	11:00
250 ft Downstream of End Sill (2+50A)						
75 Left	11.3	11:30	8.7	11:30	5.4	11:00
25 Left	11.1	12:00	7.3	12:00	4.6	12:00
25 Right	7.9	12:00	4.8	12:00	2.2	12:00
300 ft Downstream of End Sill (3+00A)						
100 Left	9.8	11:00	7.3	11:00	5.2	11:00
50 Left	10.5	11:00	7.2	11:00	4.8	11:00
25 Left	10.1	11:30	4.2	11:30	2.4	11:30
25 Right	4.3	12:00	3.6	12:00T	2.2	12:00T

Note: Data plotted in Plates 53-55.
Q_C = chute discharge, Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 22
Velocities, Existing Channel Configuration, Q_C = 700 cu m/sec (25,000 cfs), Q_R = 224 cu m/sec (8,000 cfs), Tailwater El 1320.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+36.5						
21 Left	-	-	-	-	35.8	12:00
CL	-	-	-	-	34.0	12:00
21 Right	-	-	-	-	35.8	12:00
End Sill (0+00A)						
25 Left	14.2	12:00T	12.5	12:00T	7.4	12:00T
CL	15.2	12:00T	20.0	12:00	5.9	12:00T
25 Right	14.4	12:00T	11.1	12:00T	3.7	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	17.5	11:00	15.3	11:00	12.7	11:00
CL	14.9	12:00	8.4	12:00	6.2	11:00
50 Right	7.5	12:00	3.9	12:00	2.0	12:00T
250 ft Downstream of End Sill (2+50A)						
75 Left	15.8	11:00	13.2	11:00	7.0	11:00
25 Left	13.3	11:00	9.7	11:00	8.2	11:00
300 ft Downstream of End Sill (3+00A)						
100 Left	15.0	11:00	11.0	11:00	8.6	11:00
50 Left	13.5	11:00	9.1	11:00	6.8	10:00
25 Left	10.0	11:00	5.6	11:00	5.4	10:00

Note: Data plotted in Plates 56-58.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 23
Velocities, Existing Channel Configuration, Q_C = 700 cu m/sec (25,000 cfs), Q_R = 224 cu m/sec (8,000 cfs), Tailwater El 1326.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+50						
21 Left	-	-	-	-	34.4	12:00T
CL	-	-	-	-	23.9	12:00T
21 Right	-	-	-	-	34.2	12:00T
End Sill (0+00A)						
25 Left	15.5	12:00T	11.6	12:00T	4.7	12:00T
CL	15.5	12:00T	14.4	12:00T	4.7	12:00T
25 Right	15.4	12:00T	10.8	12:00T	3.2	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	15.3	11:00	6.7	11:00	9.4	11:00
CL	13.9	12:00	5.8	11:00	3.2	11:00
50 Right	8.3	12:00	4.0	12:00T	2.3	12:00T
250 ft Downstream of End Sill (2+50A)						
75 Left	12.7	11:00	9.0	11:00	5.0	11:00
25 Left	13.1	12:00T	7.5	12:00T	4.4	11:00
300 ft Downstream of End Sill (3+00A)						
100 Left	9.9	11:00	7.4	11:00	5.3	11:00
50 Left	11.7	11:30	6.5	11:30	3.1	11:30
25 Left	10.2	11:00T	5.5	11:00T	3.6	11:00T

Note: Data plotted in Plates 59-61.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 24
Velocities, Existing Channel Configuration, Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs), Tailwater El 1322.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+35						
21 Left	-	-	-	-	27.8	12:00
CL	-	-	-	-	29.6	12:00
21 Right	-	-	-	-	25.6	12:00
End Sill (0+00A)						
25 Left	17.2	11:30	11.9	11:30	5.9	12:00T
CL	16.3	12:00	22.6	11:30T	8.0	11:30T
25 Right	15.0	12:00	20.8	12:00	3.0	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	18.4	11:30	14.5	11:00	12.3	11:00
CL	17.2	12:00	8.0	11-12T	3.9	11-12T
50 Right	7.7	12:00T	3.8	11-12T	3.6	10:00T
250 ft Downstsream of End Sill (2+50A)						
75 Left	15.9	11:30T	10.7	11:30T	5.9	11:00T
25 Left	14.7	11-12T	10.1	11-12T	6.2	11:00T
300 ft Downstream of End Sill (3+00A)						
100 Left	14.6	11:30	12.0	10-11T	6.2	11:00
50 Left	13.8	11:30	8.6	10-11T	4.5	10:00T
25 Left	11.4	11:30T	6.0	10-11T	4.7	9:00T

Note: Data plotted in Plates 62-64.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 25
Velocities, Existing Design, Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs), Tailwater El 1322.5

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+35						
21 Left	-	-	-	-	35.6	12:00
CL	-	-	-	-	34.3	12:00
21 Right	-	-	-	-	28.7	12:00
Sta 12+00						
21 Left	6.6	12:00T	18.8	12:00T	42.6	12:00T
CL	7.9	12:00T	14.0	12:00T	13.8	12:00T
21 Right	6.2	12:00T	13.8	12:00T	47.9	12:00
Sta 11+50						
21 Left	7.5	12:00T	11.6	12:00T	5.8	12:00T
CL	4.7	12:00T	27.5	12:00T	13.1	12:00T
21 Right	6.4	12:00T	15.9	12:00T	5.2	12:00T
End Sill (0+00A)						
50 Left	2.2	12:00	2.6	12:00	3.7	12:00
25 Left	17.6	12:00	14.7	12:00	7.1	12:00
CL	8.2	12:00	13.0	12:00	8.3	12:00
25 Right	5.9	12:00	11.0	12:00	3.1	12:00
50 Right	1.3	5:00	-	-	1.5	6:00
100 ft Downstream of End Sill (1+00A)						
100 Left	-	-	-	-	2.2	12:00T
75 Left	8.9	11:30	5.8	11:30	5.1	11:30
50 Left	16.7	12:00	8.5	12:00	6.1	12:00
25 Left	20.5	12:00	13.5	12:00	8.9	12:00
CL	20.8	12:00	10.8	12:00	6.9	12:00
25 Right	17.0	12:00	5.0	12:00T	2.9	12:00T
50 Right	7.6	12:00	4.3	12:00	4.5	9:30

(Sheet 1 of 3)

Note: Data plotted in Plates 65-67.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 25 (Continued)

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
100 ft Downstream of End Sill (1+00A) (continued)						
75 Right	*2.4*	*9:30*	-	-	*3.6*	*9:00*
200 ft Downstream of End Sill (2+00A)						
125 Left	-	-	-	-	7.3	12:00
75 Left	11.6	12:00	11.0	12:00	8.7	12:00
50 Left	17.0	12:00	12.8	12:00	10.1	12:00
CL	17.5	12:00	18.4	12:00	4.4	12:00
50 Right	8.4	12:00	5.4	12:00	2.9	12:00
250 ft Downstream of End Sill (2+50A)						
150 Left	2.2	12:00T	-	-	2.0	12:00T
125 Left	11.9	11:30	8.5	11:30	5.9	11:30
75 Left	16.5	11:30	12.2	11:30	6.9	11:30
25 Left	15.8	11:30	11.5	11:30	7.9	11:30
25 Right	9.1	12:00	5.1	12:00	2.6	12:00
75 Right	3.4	2:00	3.6	2:00	4.1	3:00
300 ft Downstream of End Sill (3+00A)						
175 Left	2.6	11:00	-	-	2.9	11:00
150 Left	9.5	11:00	7.6	11:00	7.2	11:00
100 Left	14.5	11:00	12.0	11:00	8.8	11:00
50 Left	13.0	11:00	10.3	11:00	6.2	11:00
25 Left	11.1	11:00	7.2	11:00	4.5	11:00
CL	9.0	12:00	4.1	12:00T	2.8	12:00T
25 Right	5.5	12:00T	2.8	12:00T	2.6	12:00T
350 ft Downstream of End Sill (3+50A)						
250 Left	-	-	-	-	2.5	11:00T
200 Left	5.8	11:00	6.2	11:00	5.8	11:00
175 Left	10.5	11:00	9.3	11:00	8.7	11:00
125 Left	13.7	11:00	12.1	11:00	9.0	11:00
75 Left	13.5	11:00	11.1	11:00	7.9	11:00
50 Left	11.4	11:00	9.2	11:00	9.0	11:00

(Sheet 2 of 3)

Table 25 (Concluded)

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
450 ft Downstream of End Sill (4+50A)						
300Left	-	-	-	-	2.3	11:00
250 Left	8.1	11:00	8.1	11:00	6.4	11:00
225 Left	10.8	11:00	10.3	11:00	8.0	11:00
175 Left	14.1	11:00	12.9	11:00	8.7	11:00
125 Left	15.6	11:00	14.7	11:00	10.8	11:00
100 Left	12.0	11:00	10.9	11:00	8.8	11:00
500 ft Downstream of End Sill (5+00A)						
300 Left	6.5	11:00	5.5	11:00	5.3	11:00
250 Left	11.4	11:00	9.8	11:00	7.1	11:00
225 Left	11.5	11:00	10.8	11:00	9.1	11:00
175 Left	14.6	11:00	13.4	11:00	10.2	11:00
125 Left	4.4	11:30	2.6	11:30	2.4	11:30
550 ft Downstream of End Sill (5+50A)						
300 Left	8.3	11:00	7.5	11:00	6.3	11:00
250 Left	11.5	11:00	10.2	11:00	8.2	11:00
225 Left	12.2	11:00	11.5	11:00	9.0	11:00
175 Left	14.7	11:00	11.5	11:00	8.9	11:00
125 Left	2.1	12:00	-	-	3.0	12:00

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Table 26
Velocities, Existing Channel Configuration, Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs), Tailwater El 1328.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+56						
21 Left	-	-	-	-	11.3	12:00
CL	-	-	-	-	18.8	12:00
21 Right	-	-	-	-	12.3	12:00
End Sill (0+00A)						
25 Left	16.0	12:00	14.2	12:00	4.1	12:00
CL	16.0	12:00	16.1	12:00	4.6	12:00
25 Right	15.1	12:00	10.8	12:00	2.9	12:00
200 ft Downstream of End Sill (2+00A)						
50 Left	9.4	11:00T	5.6	11:00T	2.7	11:00T
CL	15.6	12:00T	7.4	11:00T	3.7	11:00T
50 Right	15.6	11:00T	11.2	11:00T	8.2	11:00T
250 ft Downstream of End Sill (2+50A)						
75 Left	13.5	11:30	8.9	11:30T	4.7	11:00
25 Left	15.5	11:00T	8.5	11:00T	4.7	11:00T
300 ft Downstream of End Sill (3+00A)						
100 Left	11.3	11:30	7.5	11:00T	4.7	11:00
50 Left	14.0	11:30T	8.0	11:30T	4.1	11:00
25 Left	11.8	12:00T	6.9	12:00T	2.6	11:30T

Note: Data plotted in Plates 68-70.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 27
Velocities, Existing Channel Configuration, Q_C = 1,044 cu m/sec (37,300 cfs), Q_R = 812 cu m/sec (29,000 cfs), Tailwater El 1326.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+35						
21 Left	-	-	-	-	50.1	12:00T
CL	-	-	-	-	66.6	12:00T
21 Right	-	-	-	-	42.8	12:00T
End Sill (0+00A)						
25 Left	18.5	12:00T	6.6	12:00T	7.0	12:00T
CL	25.3	12:00T	25.0	12:00T	5.4	12:00T
25 Right	17.2	12:00T	7.0	12:00T	3.8	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	15.1	11:00	15.0	11:30	11.5	11:00
CL	20.5	12:00	9.2	10:00	7.1	10:00
50 Right	12.2	12:00	5.0	9:00	5.8	9:00
250 ft Downstream of End Sill (2+50A)						
75 Left	19.0	11:30	16.0	11:00T	6.4	11:00T
25 Left	19.7	11:30T	11.7	10:00T	8.6	9-10
300 ft Downstream of End Sill (3+00A)						
100 Left	18.3	11:30	10.6	11:30	6.1	11:00
50 Left	17.1	11:30	10.2	11:00	5.3	11:00
25 Left	16.6	11-12T	6.2	9:00T	9.1	9:00T

Note: Data plotted in Plates 71-73.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 28
Velocities, Existing Design, Q_C = 1,044 cu m/sec (37,300 cfs), Q_R = 812 cu m/sec (29,000 cfs), Tailwater El 1327.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+35						
21 Left	-	-	-	-	68.2	12:00
CL	-	-	-	-	74.1	12:00
21 Right	-	-	-	-	66.5	12:00
Sta 12+00						
21 Left	-	-	-	-	75.1	12:00T
CL	-	-	-	-	62.8	12:00T
21 Right	-	-	-	-	69.5	12:00
Sta 11+50						
21 Left	25.2	12:00T	11.6	12:00T	5.4	12:00T
CL	35.4	12:00T	35.4	12:00T	21.1	12:00T
21 Right	6.2	12:00T	8.8	12:00T	24.9	12:00T
End Sill (0+00A)						
100 Left	4.2	4:00	-	-	5.1	4:00
75 Left	2.3	5:00	3.3	5:00	3.3	5:00
50 Left	6.2	12:00T	2.0	12:00T	3.0	12:00T
25 Left	19.0	12:00T	6.8	12:00T	3.6	12:00T
CL	19.4	12:00	24.9	12:00	5.7	12:00T
25 Right	16.4	12:00T	7.3	12:00T	2.7	12:00T
50 Right	6.5	1:00T	1.3	12:00T	2.8	12:00T
100 ft Downstream of End Sill (1+00A)						
125 Left	-	-	-	-	3.1	9:00
100 Left	5.9	9:30T	3.5	9:30T	2.9	9:30T
75 Left	9.2	10:00T	7.3	10:00	8.1	10:00
50 Left	19.5	11:30	12.9	11:30	7.5	11:30T

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Note: Data plotted in Plates 74-76.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 28 (Continued)

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
100 ft Downstream of End Sill (1+00A) (Continued)						
25 Left	21.9	11:30	12.8	11:30	5.4	11:30T
CL	22.7	12:00	12.7	12:00	4.4	12:00T
25 Right	19.8	12:00	8.6	12:00T	2.0	12:00T
50 Right	10.6	1-2T	2.3	12:00	1.5	12:00T
75 Right	5.1	9:00	1.8	9:00	3.0	9:00T
200 ft Downstream of End Sill (2+00A)						
150 Left	-	-	-	-	9.4	11:30
125 Left	12.9	11:00	10.1	11:00	8.9	11:30
75 Left	14.8	11:00	11.7	11:00	8.0	11:00
50 Left	21.3	11:00	15.2	11:00	10.8	11:00
CL	22.1	12:00	10.2	12:00	2.4	12:00T
50 Right	11.5	12:00	3.6	12:00	5.5	8:30
100 Right	2.6	9:00	2.7	9:00	2.2	9:00
250 ft Downstream of End Sill (2+50A)						
175 Left	-	-	-	-	6.9	11:30
150 Left	11.4	11:00	8.8	11:00	7.3	11:00
125 Left	14.2	11:00	10.5	11:00	8.9	11:00
75 Left	18.8	11:00	11.2	11:00	5.2	11:00T
25 Left	19.8	11:30	11.9	11:30	6.7	10:00T
25 Right	14.7	12:00	5.9	9:00	4.3	10:00T
75 Right	3.3	9:00	4.1	9:00	2.3	8:00
300 ft Downstream of End Sill (3+00A)						
200 Left	6.3	11:00	6.8	11:00	6.7	11:00
175 Left	12.2	11:00	9.8	11:00	7.3	11:00
150 Left	14.6	11:00	11.8	11:00	9.8	11:00
100 Left	17.0	11:30	10.7	11:00	7.0	11:00T
50 Left	18.8	11:30	11.5	10:00	6.0	11:00
25 Left	8.5	11:30	10.8	10-11T	5.8	10:00

(Sheet 2 of 3)

Table 28 (Concluded)						
Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
300 ft Downstream of End Sill (3+00A) (Continued)						
CL	12.6	12:00	8.7	10:00T	4.4	10:00T
25 Right	9.4	11-12	6.9	9-10T	4.9	9:00T
75 Right	3.4	9:00	2.5	9:00	2.5	9:00T
350 ft Downstream of End Sill (3+50A)						
200 Left	12.3	11:00	11.4	11:00	8.7	11:00
175 Left	13.9	11:00	11.8	11:00	8.2	11:00
125 Left	16.4	11:00	13.0	11:00	10.0	11:00
75 Left	18.4	11:00	12.4	11:00	8.2	11:00
50 Left	17.0	11:00	13.1	11:00	11.6	11:00
450 ft Downstream of End Sill (4+50A)						
300 Left	-	-	-	-	1.7	11:30
250 Left	12.1	11:00	9.6	11:00	8.0	11:00
225 Left	12.7	11:00	11.2	11:00	8.8	11:00
175 Left	14.9	11:00	13.7	11:00	12.3	11:00
125 Left	17.5	11:00	17.0	11:00	12.7	11:00
100 Left	18.8	11:00	16.2	11:00	12.9	11:00
50 Left	-	-	-	-	12.1	11:00
500 ft Downstream of End Sill (5+00A)						
300 Left	8.9	11:00	8.7	11:00	5.6	11:00
250 Left	13.1	11:30	11.8	11:30	8.5	11:30
225 Left	13.5	11:30	12.3	11:30	7.4	11:30
175 Left	16.5	11:30	16.4	11:30	12.3	11:00
125 Left	16.3	11:00	13.6	11:00	11.4	11:00
100 Left	-	-	-	-	2.6	11:00
550 ft Downstream of End Sill (5+50A)						
300 Left	12.1	11:00	9.6	11:00	7.0	11:00
250 Left	13.1	11:00	11.4	11:00	7.6	11:00
225 Left	13.8	11:00	12.8	11:00	9.0	11:00
175 Left	17.2	11:00	14.7	11:00	6.1	11:00
125 Left	3.3	12:00	1.8	12:00	1.9	11:00

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Table 29
Velocities, Existing Channel Configuration, Q_C = 1,044 cu m/sec (37,300 cfs), Q_R = 812 cu m/sec (29,000 cfs), Tailwater El 1330.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity, fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+50						
21 Left	-	-	-	-	41.7	12:00T
CL	-	-	-	-	48.1	12:00T
21 Right	-	-	-	-	58.8	12:00T
End Sill (0+00A)						
25 Left	19.1	12:00T	8.2	12:00T	4.0	12:00T
CL	17.6	12:00T	23.0	12:00T	5.1	12:00T
25 Right	17.3	12:00T	6.2	12:00T	3.2	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	21.0	11:30-12:00T	13.0	11:30-12:00T	8.4	11:00T
CL	17.6	12:00	7.6	12:00	4.8	11:00T
50 Right	10.2	12:00T	5.9	9:00	4.2	9:00
250 ft Downstream of End Sill (2+50A)						
75 Left	17.2	11:00-11:30T	10.4	11:30T	5.6	10-11T
25 Left	16.8	12:00T	10.0	10-11T	7.3	9:00T
300 ft Downstream of End Sill (3+00A)						
100 Left	16.9	11:30	8.8	11:30	5.3	11:00
50 Left	16.6	11:30	9.0	11:00	4.9	11:00
25 Left	15.0	11-12T	9.8	9:00T	6.7	9:00T

Note: Data plotted in Plates 77-79
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 30
Center-line Wave Elevations in Exit Channel, Existing Channel Configuration, Type 1 Stilling Basin

Distance Downstream of End Sill, ft[1]	Q_C = 591 cu m/sec (21,100 cfs) Q_R = 174 cu m/sec (6,200 cfs) Tailwater El 1320.2		Q_C = 812 cu m/sec (29,000 cfs) Q_R = 204 cu m/sec (7,300 cfs) Tailwater El 1322.5		Q_C = 1,044 cu m/sec (37,300 cfs) Q_R = 812 cu m/sec (29,000 cfs) Tailwater El 1327.0	
	Max	**Min**	**Max**	**Min**	**Max**	**Min**
50	1322.4	1321.7	1324.4	1323.2	1330.4	1327.2
100	1322.3	1321.5	1323.3	1322.4	1331.4	1329.3
200	1321.3	1320.8	1322.9	1322.4	1328.8	1327.3
250	1320.9	1320.8	1323.5	1322.5	1328.5	1327.9
300	1321.5	1321.2	1323.7	1323.1	1329.3	1328.4

Note: Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.

Table 31
d_1, v_1, d_2, and v_2 Existing Channel Configuration, Type 1 Stilling Basin

Location of Measurement	Q_C = 591 cu m/sec (21,100 cfs), Q_R = 174 cu m/sec (6,200 cfs)							
	Tailwater El 1318.0				Tailwater El 1324.0			
	Sta 12+50		End Sill		Sta 12+64		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Left wall	5.3	18.9	27.0	14.6 (s) 12.4 (m) 7.1 (b)	8.9	20.0	31.4	15.3 (s) 10.8 (m) 4.6 (b)
Center l ine	4.7	19.7	26.6	14.9 (s) 16.6 (m) 4.1 (b)	8.5	17.4	31.3	16.1 (s) 11.1 (m) 3.5 (b)
Right wall	5.1	22.6	26.8	13.1 (s) 9.9 (m) 4.7 (b)	9.1	17.3	31.6	14.8 (s) 7.9 (m) 4.0 (b)
Location of Measurement	Q_C = 700 cu m/sec (25,000 cfs), Q_R = 224 cu m/sec (8,000 cfs)							
	Tailwater El 1320.0				Tailwater El 1326.0			
	Sta 12+36.5		End Sill		Sta 12+50		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Left wall	4.9	35.8	28.9	14.2 (s) 12.5 (m) 7.4 (b)	6.9	34.4	33.2	15.5 (s) 11.6 (m) 4.7 (b)
Center line	4.8	34.0	29.3	15.2 (s) 20.0 (m) 5.9 (b)	7.6	23.9	34.1	15.5 (s) 14.4 (m) 4.7 (b)

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Note: Data plotted in Plates 80-82.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
d_1= tailwater depth entering stilling basin, d_2 = hydraulic jump secant depth.
v_1 = velocity entering stilling basin, v_2 = velocity at hydraulic jump secant depth.
s = surface, m = middepth, b = bottom.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.

Table 31 (Continued)

Location of Measurement	Q_C = 700 cu m/sec (25,000 cfs), Q_R = 224 cu m/sec (8,000 cfs) (continued)							
	Tailwater El 1320.0				Tailwater El 1326.0			
	Sta 12+36.5		End Sill		Sta 12+50		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Right wall	4.9	35.8	28.5	14.4 (s) 11.1 (m) 3.7 (b)	8.0	34.2	33.9	15.4 (s) 10.8 (m) 3.2 (b)

Location of Measurement	Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs)							
	Tailwater El 1322.0				Tailwater El 1322.5			
	Sta 12+35		End Sill		Sta 12+35		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Left wall	8.5	27.8	28.8	17.2 (s) 11.9 (m) 5.9 (b)	8.6	35.6	28.6	17.6 (s) 14.7 (m) 7.1 (b)
Center line	8.4	29.6	29.5	16.3 (s) 22.6 (m) 8.0 (b)	9.0	34.3	29.9	8.2 (s) 13.0 (m) 8.3 (b)
Right wall	8.3	25.6	28.4	15.0 (s) 20.8 (m) 3.0 (b)	8.7	28.7	29.1	5.9 (s) 11.0 (m) 3.1 (b)

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Table 31 (Concluded)

Location of Measurement	Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs)				Q_C = 1,044 cu m/sec (37,300 cfs), Q_R = 812 cu m/sec (29,000 cfs)			
	Tailwater El 1328.0				Tailwater El 1326.0			
	Sta 12+56		End Sill		Sta 12+35		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Left wall	8.8	11.3	34.1	16.0 (s) 14.2 (m) 4.1 (b)	12.0	50.1	28.8	18.5 (s) 6.6 (m) 7.0 (b)
Center line	7.6	18.8	36.1	16.0 (s) 16.1 (m) 4.6 (b)	12.2	66.6	29.5	25.3 (s) 25.0 (m) 5.4 (b)
Right wall	8.6	12.3	35.7	15.1 (s) 10.8 (m) 2.9 (b)	12.3	42.8	28.4	17.2 (s) 7.0 (m) 3.8 (b)

Location of Measurement	Q_C = 1,044 cu m/sec (37,300 cfs), Q_R = 812 cu m/sec (29,000 cfs)							
	Tailwater El 1327.0				Tailwater El 1330.0			
	Sta 12+35		End Sill		Sta 12+50		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Left wall	7.5	68.2	28.6	19.0 (s) 6.8 (m) 3.6 (b)	7.9	41.7	41.5	19.1 (s) 8.2 (m) 4.0 (b)
Center line	7.5	74.1	29.9	19.4 (s) 24.9 (m) 5.7 (b)	7.4	48.1	41.2	17.6 (s) 23.0 (m) 5.1 (b)
Right wall	7.2	66.5	29.1	16.4 (s) 7.3 (m) 2.7 (b)	7.3	58.8	40.2	17.3 (s) 6.2 (m) 3.2 (b)

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Table 32
Water-Surface Elevations, Type 2 Stilling Basin, Q_C = 700 cu m/sec (25,000 cfs), Q_R = 224 cu m/sec (8,000 cfs)

Sta	Distance from Center Line, ft[1]	Tailwater El 1320.0	Tailwater El 1326.0
12+65	21 Left	-	1306.1
	CL	-	1306.4
	21 Right	-	1306.1
12+50	21 Left	1301.0	-
	CL	1300.6	-
	21 Right	1300.8	-
End sill	25 Left	1322.0	1325.7
	CL	1322.6	1326.3
	25 Right	1322.9	1320.9
2+00A	50 Left	1320.5	1325.6
	CL	1321.3	1326.0
	50 Right	1321.7	1325.9
2+50A	75 Left	1320.7	1326.1
	25 Left	1320.8	1325.9
3+00A	100 Left	1321.0	1326.0
	50 Left	1321.1	1326.0
	25 Left	1321.6	1326.2

Note: Data plotted in Plates 84 and 85.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.

Table 33
Water-Surface Elevations, Type 2 Stilling Basin, Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs)

Sta	Distance from Center Line, ft[1]	Tailwater El 1322.0	Tailwater El 1328.0
12+74	21 Left	-	1310.5
	CL	-	1310.8
	21 Right	-	1310.7
12+38	21 Left	1302.0	-
	CL	1301.9	-
	21 Right	1301.5	-
End Sill	25 Left	1327.9	1332.1
	CL	1327.8	1331.8
	25 Right	1327.4	1331.9
2+00A	50 Left	1323.2	1327.9
	CL	1323.0	1328.2
	50 Right	1322.8	1327.6
2+50A	75 Left	1322.4	1328.8
	25 Left	1322.8	1328.2
3+00A	100 Left	1322.2	1328.0
	50 Left	1321.7	1329.5
	25 Left	1322.8	1328.8

Note: Data plotted in Plates 86 and 87.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.

Table 34
Water-Surface Elevations, Type 2 Stilling Basin, Q_C = 1,044 cu m/sec (37,300 cfs), Q_R = 812 cu m/sec (29,000 cfs)

Sta	Distance from Center Line, ft[1]	Tailwater El 1326.0	Tailwater El 1330.0
12+57.5	21 Left	-	1308.2
	CL	-	1308.6
	21 Right	-	1307.8
12+38	21 Left	1301.5	-
	CL	1301.4	-
	21 Right	1302.3	-
End Sill	25 Left	1334.5	1336.5
	CL	1335.1	1336.9
	25 Right	1332.8	1335.9
2+00A	50 Left	1325.4	1328.9
	CL	1327.3	1330.0
	50 Right	1328.2	1330.4
2+50A	75 Left	1327.5	1329.9
	25 Left	1327.3	1330.7
3+00A	100 Left	1326.1	1330.1
	50 Left	1326.5	1330.3
	25 Left	1327.0	1330.3

Note: Data plotted in Plates 88 and 89.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.

Table 35
Velocities, Type 2 Stilling Basin, Q_C = 700 cu m/sec (25,000 cfs), Q_R = 224 cu m/sec (8,000 cfs), Tailwater El 1320.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+50						
21 Left	-	-	-	-	11.4	12:00
CL	-	-	-	-	14.0	12:00
21 Right	-	-	-	-	11.4	12:00
End Sill (0+00A)						
25 Left	18.0	12:00	16.2	12:00	5.9	12:00T
CL	19.0	12:00	18.8	12:00	5.1	12:00T
25 Right	17.5	12:00	14.7	12:00	7.2	12:00
200 ft Downstream of End Sill (2+00A)						
50 Left	17.7	11:30	13.7	11:30	13.0	11:30
CL	16.0	11:30	7.6	11:30	5.7	11:00T
50 Right	7.3	12:00	3.4	12:00	4.1	9:00
250 ft Downstream of End Sill (2+50A)						
75 Left	14.5	11:00	13.6	11:00	10.3	11:00
25 Left	15.2	11:00	10.6	11:00	7.5	11:00
300 ft Downstream of End Sill (3+00A)						
100 Left	13.3	11:00	11.5	11:00	7.7	11:00
50 Left	14.4	11:00	9.1	11:00	5.4	11:00
25 Left	11.9	11:00	8.1	11:00	5.0	10:30

Note: Data plotted in Plates 90-92.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 36
Velocities, Type 2 Stilling Basin, Q_C = 700 cu m/sec (25,000 cfs), Q_R = 224 cu m/sec (8,000 cfs), Tailwater El 1326.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+65						
21 Left	-	-	-	-	17.8	1:00
CL	-	-	-	-	20.7	1:00
21 Right	-	-	-	-	27.8	1:00
End Sill (0+00A)						
25 Left	18.5	12:00	14.0	12:00	3.2	12:00T
CL	18.8	12:00	11.4	12:00	2.3	12:00T
25 Right	17.9	12:00T	11.6	12:00T	3.9	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	14.9	11:00	11.9	11:00	9.6	11:00
CL	15.0	11:00	7.2	11:00T	3.3	11:00T
50 Right	7.8	12:00T	4.6	12:00T	2.0	12:00T
250 ft Downstream of End Sill (2+50A)						
75 Left	11.7	11:00	9.6	11:00	5.3	11:00
25 Left	12.9	11:30	6.1	11:00	4.3	11:30T
300 ft Downstream of End Sill (3+00A)						
100 Left	10.1	11:00	9.0	10:30	6.5	10:00
50 Left	13.9	11:00	8.4	11:00	4.6	11:00T
25 Left	10.0	11:00	5.0	11:00T	2.4	11:00

Note: Data plotted in Plates 93-95.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 37
Velocities, Type 2 Stilling Basin, Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs), Tailwater El 1322.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+38						
21 Left	-	-	-	-	34.2	12:00
CL	-	-	-	-	20.6	12:00
21 Right	-	-	-	-	33.1	12:00
End Sill (0+00A)						
25 Left	18.2	12:00	16.8	12:00	5.9	12:00
CL	19.1	12:00	17.4	12:00	3.9	12:00
25 Right	17.7	12:00	15.0	12:00	6.9	12:00
200 ft Downstream of End Sill (2+00A)						
50 Left	17.6	11:30	15.4	11:30	13.0	11:00
CL	16.0	12:00T	8.6	10:00	6.3	10-11T
50 Right	8.0	12:00T	4.5	10-12T	3.9	9:00T
250 ft Downstream of End Sill (2+50A)						
75 Left	14.8	11:30	11.5	11:30	6.2	11:00
25 Left	16.4	11:30	8.0	11:30	6.7	10:00
300 ft Downstream of End Sill (3+00A)						
100 Left	13.2	11:00	11.6	11:00	7.9	11:00
50 Left	15.6	11:00	9.0	11:00	5.0	11:00
25 Left	11.9	11:30	5.8	11-12T	4.5	10:00

Note: Data plotted in Plates 96-98.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 38
Velocities, Type 2 Stilling Basin, Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs), Tailwater El 1328.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+74						
21 Left	-	-	-	-	14.6	12:00
CL	-	-	-	-	16.3	12:00
21 Right	-	-	-	-	13.3	12:00
End Sill (0+00A)						
25 Left	17.8	12:00T	11.6	12:00T	3.8	12:00T
CL	18.6	12:00T	10.1	12:00T	2.5	12:00T
25 Right	18.2	12:00T	13.8	12:00T	4.4	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	8.4	12:00	3.9	11:30	2.4	11:00
CL	15.8	12:00	5.0	12:00	3.4	12:00T
50 Right	18.0	11:30	11.8	11:30	9.5	11:30
250 ft Downstream of End Sill (2+50A)						
75 Left	12.2	11:30	10.3	11:30	6.5	11:00
25 Left	15.1	12:00	7.5	12:00	4.5	12:00T
300 ft Downstream of End Sill (3+00A)						
100 Left	10.1	11:00	9.6	11:00	6.4	11:00
50 Left	14.4	11:30	8.8	11:30	4.3	11:30
25L(.83)	12.6	12:00	6.4	12:00T	2.2	12:00T

Note: Data plotted in Plates 99-101.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 39
Velocities, Type 2 Stilling Basin, Q_C = 1,044 cu m/sec (37,300 cfs), Q_R = 812 cu m/sec (29,000 cfs), Tailwater El 1326.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+38						
21 Left	-	-	-	-	66.4	12:00T
CL	-	-	-	-	59.3	12:00
21 Right	-	-	-	-	59.9	12:00
End Sill (0+00A)						
25 Left	20.5	12:00T	12.2	12:00T	3.4	12:00T
CL	20.0	12:00T	20.8	12:00	3.6	12:00T
25 Right	19.8	12:00T	10.6	12:00T	3.5	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	23.3	11:30	16.5	11:30	13.6	11:00
CL	20.1	12:00	5.3	9:00T	6.9	9:00T
50 Right	8.5	12:00	5.2	9:00	4.9	9 :00
250 ft Downstream of End Sill (2+50A)						-
75 Left	19.9	11:30	14.0	11-12T	9.3	11:00T
25 Left	17.3	11:00T	11.7	11:00T	9.5	9:00
300 ft Downstream of End Sill (3+00A)						
100 Left	21.4	11:30	14.2	11:00T	5.4	11:00
50 Left	20.2	12:00	12.2	9-10T	8.2	9-10T
25 Left	18.2	11:30	8.8	9:00T	8.0	10:00T

Note: Data plotted in Plates 102-104.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 40
Velocities, Type 2 Stilling Basin, Q_C = 1,044 cu m/sec (37,300 cfs), Q_R = 812 cu m/sec (29,000 cfs), Tailwater El 1330.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
Sta 12+57.5						
21 Left	-	-	-	-	65.6	12:00
CL	-	-	-	-	69.2	12:00
21 Right	-	-	-	-	64.3	12:00
End Sill (0+00A)						
25 Left	20.6	12:00T	11.4	12:00T	3.0	12:00
CL	20.2	12:00T	17.1	12:00T	3.4	12:00T
25 Right	18.7	12:00T	10.5	12:00T	3.4	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	20.8	11:00	16.0	11:00	11.3	11:00
CL	17.8	12:00	8.5	10-12T	4.7	11:00T
50 Right	11.2	12:00	4.7	9:00T	4.9	9:00T
250 ft Downstream of End Sill (2+50A)						
75 Left	16.8	11:30	11.1	11:30	6.0	11:00T
25 Left	17.6	12:00	10.1	10:00T	6.2	10:00
300 ft Downstream of End Sill (3+00A)						
100 Left	14.5	11:00	11.4	11:00	6.6	11:00
50 Left	17.6	11:30	10.0	10-11T	5.4	10-11T
25 Left	15.8	11:30	7.3	11:00T	3.4	10:00T

Note: Data plotted in Plates 105-107.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1] To convert from ft to m multiply by 0.3048.
[2] To convert from fps to m/sec multiply by 0.3048.
[3] 12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 41
d_1, v_1, d_2, and v_2, Existing Channel Configuration, Type 2 Stilling Basin

Location of Measurement	Q_C = 700 cu m/sec (25,000 cfs), Q_R = 224 cu m/sec (8,000 cfs)							
	Tailwater El 1320.0				Tailwater El 1326.0			
	Sta 12+50		End Sill		Sta 12+65		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Left wall	5.0	11.4	27.0	18.0 (s) 16.2 (m) 5.9 (b)	7.2	17.8	30.7	18.5 (s) 14.0 (m) 3.2 (b)
Center line	4.6	14.0	27.6	19.0 (s) 18.8 (m) 5.1 (b)	7.5	20.7	31.3	18.8 (s) 11.4 (m) 2.3 (b)
Right wall	4.8	11.4	27.9	17.5 (s) 14.7 (m) 7.2 (b)	7.2	27.8	25.9	17.9 (s) 11.6 (m) 3.9 (b)

Location of Measurement	Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs)							
	Tailwater El 1322.0				Tailwater El 1328.0			
	Sta 12+38		End Sill		Sta 12+74		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Left wall	8.3	34.2	32.9	18.2 (s) 16.8 (m) 5.9 (b)	10.2	14.6	37.1	17.8 (s) 11.6 (m) 3.8 (b)
Center line	8.2	20.6	32.8	19.1 (s) 17.4 (m) 3.9 (b)	10.5	16.3	36.8	18.6 (s) 10.1 (m) 2.5 (b)

(Continued)

Note: Data plotted in Plates 108-110.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
d_1 = tailwater depth entering stilling basin, d_2 = hydraulic jump secant depth.
v_1 = velocity entering stilling basin, v_2 = velocity at hydraulic jump secant depth.
s = surface, m = mid-depth, b = bottom.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.

Table 41 (Concluded)

Location of Measurement	Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs) (continued)							
	Tailwater El 1322.0				Tailwater El 1328.0			
	Sta 12+38		End Sill		Sta 12+74		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Right wall	7.8	33.1	32.4	17.7 (s) 15.0 (m) 6.9 (b)	10.4	13.3	36.9	18.2 (s) 13.8 (m) 4.4 (b)

Location of Measurement	Q_C = 1,044 cu m/sec (37,300 cfs), Q_R = 812 cu m/sec (29,000 cfs							
	Tailwater El 1326.0				Tailwater El 1330.0			
	Sta 12+38		End Sill		Sta 12+57.5		End Sill	
	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]	d_1, ft[1]	v_1, fps[2]	d_2, ft[1]	v_2, fps[2]
Left wall	7.8	66.4	39.5	20.5 (s) 12.2 (m) 3.4 (b)	9.7	65.6	41.5	20.6 (s) 11.4 (m) 3.0 (b)
Center line	7.7	59.3	40.1	20.0 (s) 20.8 (m) 3.6 (b)	10.1	69.2	41.9	20.2 (s) 17.1 (m) 3.4 (b)
Right wall	8.6	59.9	37.8	19.8 (s) 10.6 (m) 3.5 (b)	9.3	64.3	40.9	18.7 (s) 10.5 (m) 3.4 (b)

Table 42
Center-Line Wave Elevations in Exit Channel, Existing Channel Configuration, Type 2 Stilling Basin

Distance Downstream of End Sill, ft[1]	Q_C = 591 cu m/sec (21,100 cfs) Q_R = 174 cu m/sec (6,200 cfs) Tailwater El 1320.2		Q_C = 812 cu m/sec (29,000 cfs) Q_R = 204 cu m/sec (7,300 cfs) Tailwater El 1322.5		Q_C = 1,044 cu m/sec (37,300 cfs) Q_R = 812 cu m/sec (29,000 cfs) Tailwater El 1327.0	
	Max	Min	Max	Min	Max	Min
50	1322.4	1321.5	1327.2	1323.6	1326.6	1325.8
100	1322.5	1321.9	1322.8	1322.2	1333.3	1331.2
200	1321.3	1321.0	1324.3	1323.0	1329.6	1328.4
250	1321.6	1321.2	1323.9	1323.2	1329.1	1328.2
300	1321.8	1321.4	1323.7	1323.5	1328.9	1327.9

Note: Data plotted in Plates 105-107.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.

Table 43
Water-Surface Elevations, Realigned Channel, Type 1 Stilling Basin

Distance from Center Line, ft[1]	Q_C = 356 cu m/sec (12,700 cfs) Q_R = 6 cu m/sec (200 cfs) Tailwater El 1315.0	Q_C = 591 cu m/sec (21,100 cfs) Q_R = 174 cu m/sec (6,200 cfs) Tailwater El 1320.2	Q_C = 812 cu m/sec (29,000 cfs) Q_R = 204 cu m/sec 7,300 cfs Tailwater El 1322.5	Q_C = 1,044 cu m/sec (37,300 cfs) Q_R = 812 cu m/sec (29,000 cfs) Tailwater El 1327.0
End Sill (0+00A)				
25 Left	1317.8	1324.1	1327.4	1340.4
CL	1317.2	1323.3	1327.4	1340.4
25 Right	1317.3	1324.2	1327.3	1355.0
200 ft Downstream of End Sill (2+00A)				
125 Left	-	-	1323.3	1327.8
100 Left	-	1320.5	1323.7	1327.3
50 Left	1315.9	1320.3	1323.7	1329.8
CL	1316.0	1320.8	1324.1	1332.0
50 Right	1315.9	1321.0	1323.9	1328.9
75 Right	-	-	-	1330.4
100 Right	-	-	1323.8	-
250 ft Downstream of End Sill (2+50A)				
150 Left	-	-	1323.2	1327.7
125 Left	-	-	1323.4	1327.9
75 Left	1315.6	1320.7	1324.8	1330.1

(Continued)

Note: Data plotted in Plates 113-116.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.

Table 43 (Concluded)				
Distance from Center Line, ft[1]	Q_C = 356 cu m/sec (12,700 cfs) Q_R = 6 cu m/sec (200 cfs) Tailwater El 1315.0	Q_C = 591 cu m/sec (21,100 cfs) Q_R = 174 cu m/sec (6,200 cfs) Tailwater El 1320.2	Q_C = 812 cu m/sec (29,000 cfs) Q_R = 204 cu m/sec 7,300 cfs Tailwater El 1322.5	Q_C = 1,044 cu m/sec (37,300 cfs) Q_R = 812 cu m/sec (29,000 cfs) Tailwater El 1327.0
250 ft Downstream of End Sill (2+50A) (Continued)				
25 Left	1315.6	1320.7	1323.5	1330.8
25 Right	1315.9	1320.8	1323.5	1329.3
50 Right	1315.9	-	-	-
75 Right	-	-	1323.5	1329.7
300 ft Downstream of End Sill (3+00A)				
175 Left	-	-	-	1327.6
150 Left	-	-	1323.4	1328.2
125 Left	-	-	1323.7	-
100 Left	1315.5	1320.7	-	1328.8
75 Left	-	-	1324.3	-
50 Left	1315.8	1320.9	-	1329.4
25 Left	1315.9	1320.9	1323.9	1328.9
CL	1316.0	1320.7	1324.1	1328.7
25 Right	-	-	1323.6	-
50 Right	-	-	-	1328.5
75 Right	-	-	1323.3	-

Table 44
Velocities, Realigned Channel Configuration, Q_C = 356 cu m/sec (12,700 cfs), Tailwater El 1315.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
End Sill (0+00A)						
25 Left	12.9	12:00	9.7	12:00	5.4	12:00T
CL	12.8	12:00	10.2	12:00	2.9	12:00T
25 Right	11.4	12:00	6.6	12:00	5.2	12:00T
200 ft Downstream of End Sill (2+00A)						
50 Left	8.8	12:00	8.2	12:00	7.6	12:00
CL	9.7	12:00	8.2	12:00	7.2	11:30
50 Right	5.0	12:00	3.8	12:00	4.0	12:00
250 ft Downstream of End Sill (2+50A)						
75 Left	7.6	12:00	4.8	12:00	3.1	12:00
25 Left	8.8	12:00	8.1	11:30	7.6	11:30
25 Right	7.7	12:00	7.6	12:00	7.1	12:00
50 Right	4.2	12:00	4.0	12:00	3.6	12:00
300 ft Downstream of End Sill (3+00A)						
100 Left	3.8	11:00	2.2	11:00	2.6	11:00
50 Left	7.3	11:30	6.8	11:30	6.5	11:30
25 Left	7.6	12:00	6.6	12:00	5.7	12:00
CL	7.6	12:00	6.9	12:00	5.9	12:00

Note: Data plotted in Plates 117-119.
Q_C = chute discharge; Q_R = Big Sioux River discharge.

[1]To convert from ft to m multiply by 0.3048.

[2]To convert from fps to m/sec multiply by 0.3048.

[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 45
Velocities, Realigned Channel Configuration, Q_C = 591 cu m/sec (21,100 cfs), Q_R = 174 cu m/sec (6,200 cfs), Tailwater El 1320.2

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
End Sill (0+00A)						
25 Left	14.4	12:00	11.2	12:00	6.9	12:00T
CL	14.6	12:00	16.2	12:00T	3.9	12:00T
25 Right	12.4	12:00T	9.9	12:00T	5.2	12:00T
200 ft Downstream of End Sill (2+00A)						
100 Left	9.0	12:00	7.8	12:00	6.8	12:00
50 Left	14.3	11:30	11.9	12:00	10.9	11:30
CL	14.4	12:00	9.0	12:00	6.9	11:30T
50 Right	7.2	12:00T	3.9	12:00T	3.7	10:30
250 ft Downstream of End sill (2+50A)						
75 Left	11.6	11:30	9.8	11:30	5.7	11:30
25 Left	12.6	11:30	11.3	11:30	7.7	11:30
25 Right	8.3	11:30-12	5.8	11:30-12	4.6	11:00
300 ft Downstream of End Sill (3+00A)						
100 Left	1.9	11:30	8.1	11:30	6.6	11:00
50 Left	12.0	11:30	9.4	11:30	7.6	11:30
25 Left	10.3	11:30T	8.9	11:30T	6.9	11:30T
CL	8.7	11:30T	6.2	11:30T	4.9	11:00T

Note: Data plotted in Plates 120-122.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 46
Velocities, Realigned Channel Configuration, Q_C = 812 cu m/sec (29,000 cfs), Q_R = 204 cu m/sec (7,300 cfs) Tailwater El 1322.5

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
End Sill (0+00A)						
25 Left	18.4	12:00T	12.4	12:00T	6.8	12:00T
CL	19.4	12:00	20.3	12:00	9.6	12:00T
25 Right	18.1	12:00T	11.9	12:00T	4.0	12:00T
200 ft Downstream of End Sill (2+00A)						
125 Left	6.3	12:00	4.9	12:00	4.9	12:00T
100 Left	14.3	11:30	12.6	11:30	9.3	11:30
50 Left	18.3	11:30	15.0	11:30T	3.0	11:30T
CL	17.2	12:00T	7.7	11-12T	5.6	11:30T
50 Right	8.9	12:00T	5.8	9-10T	4.4	9:00T
100 Right	2.4	9:00	2.4	9:00	3.3	8:30-9T
250 ft Downstream of End Sill (2+50A)						
150 Left	1.7	6:00	2.4	6:00T	2.7	6:00
125 Left	8.3	11:30	4.4	11:30T	2.3	6:00T
75 Left	16.3	11:30T	12.9	11:30T	6.8	11:30T
25 Left	17.1	11:30	11.2	11:30	6.8	11:30
25 Right	10.6	12:00	6.4	12:00	4.3	11:30T
75 Right	3.5	12:00T	1.8	12:00T	1.8	6:00
300 ft Downstream of End Sill (3+00A)						
150 Left	3.8	11-12T	2.3	11:30	1.5	11:30T
100 Left	14.5	11:30	10.3	11:30	6.7	11:00
50 Left	14.8	11:30	10.0	11:30-12T	7.3	11:30
25 Left	13.5	12:00T	9.0	12:00T	5.0	12:00T
CL	11.2	12:00	7.2	12:00T	3.9	12:00T
25 Right	7.4	12:00	4.8	12:00T	2.6	12:00T
50 Right	2.5	1:00T	2.5	3:00T	2.6	6:00

(Sheet 1 of 3)

Note: Data plotted in Plates 123-125.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 46 (Continued)

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
400 ft Downstream of End Sill (4+00A)						
250 Left	1.7	6:00T	1.6	5:00T	2.2	5:00T
200 Left	4.4	11-12T	3.5	11-12T	2.3	11:30-12T
150 Left	12.0	11:30T	9.5	11:30T	6.6	11:30T
100 Left	13.8	11:30	10.7	11:30	7.5	11:30
50 Left	10.4	12:00	6.5	12:00	4.3	12:00T
CL	5.6	12:00	4.0	12:00T	3.0	12:00T
50 Right	1.9	5:00T	1.7	4:00T	3.1	5:00T
75 Right	3.4	5:00	-	-	4.2	5:00
500 ft Downstream of End Sill (5+00A)						
300 Left	1.5	10:00	1.3	5:00T	1.8	12:00T
275 Left	3.1	11:00	2.3	12:00	1.4	12:00
225 Left	9.2	11:00	8.3	11:00	6.3	11:30T
175 Left	11.8	11:00	11.8	11:00	7.9	11:00
125 Left	12.6	11:30	11.3	11:00	9.9	11:00
75 Left	9.2	11:30	7.9	11:30	7.6	11:30
50 Left	7.1	11:30	5.9	11:00	5.5	11:00
25 Left	3.6	11:00	-	-	4.5	11:00
600 ft Downstream of End Sill (6+00A)						
275 Left	9.0	11:30	7.5	11:30	5.1	12:00
225 Left	11.8	11:30	10.4	11:30	8.0	11:30
175 Left	10.8	11:00	10.6	11:00	8.7	11:00
125 Left	9.3	11:00	9.7	11:00	9.4	11:30
100 Left	9.5	11:30	8.1	11:30	6.9	11:00
700 ft Downstream of End Sill (7+00A)						
275 Left	9.1	11:30	8.4	11:30	8.1	12:00
225 Left	9.2	11:30	8.9	11:30	6.9	12:00
175 Left	8.9	11:3-	8.5	11:30	7.5	11:30
150 Left	8.2	11:30	6.7	11:30	6.4	11:30

(Sheet 2 of 3)

Table 46 (Concluded)

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
800 ft Downstream of End Sill (8+00A)						
300 Left	10.0	11:30	8.3	11:30	7.8	12:00
250 Left	10.5	11:30	9.3	11:30	7.4	12:00
200 Left	8.3	11:30	7.9	11:30	6.1	11:30
175 Left	6.9	11:30	7.4	11:30	6.3	12:00

(Sheet 3 of 3)

Table 47
Velocities, Realigned Channel Configuration, Q_C = 1,044 cu m/sec (37,300 cfs), Q_R = 812 cu m/sec (29,000 cfs), Tailwater El 1327.0

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
End Sill (0+00A)						
25 Left	17.4	12:00T	6.3	12:00T	4.3	12:00T
CL	24.2	12:00	19.1	12:00	4.2	12:00T
25 Right	12.6	12:00	4.4	12:00T	4.7	12:00T
200 ft Downstream of End Sill (2+00A)						
125 Left	12.7	11:30	10.9	11:30	9.7	11:30
100 Left	16.2	11:00	11.9	11:30	10.6	11:30
50 Left	21.4	11:30	13.8	11:30	10.1	11:30
CL	20.5	12:00T	9.1	12:00T	3.7	12:00T
50 Right	13.2	12:00	6.0	9:00	6.6	9:00
75 Left	3.8	12:00T	4.8	9:00	3.9	9:00
250 ft Downstream of End Sill (2+50A)						
150 Left	10.9	11:00	8.5	11:00	6.1	11:00
125 Left	13.9	11:00	9.6	11:00	7.2	11:00
75 Left	18.2	11:30	12.9	11:00T	6.0	10:00T
25 Left	20.5	11:30	10.8	10:00T	7.7	10-11T
25 Right	15.8	12:00	8.5	9-10T	8.2	9-10T
75 Right	5.4	9-9:30T	5.0	9:00	4.8	10:00
300 ft Downstream of End Sill (3+00A)						
175 Left	8.9	11:00	7.3	11:00	5.8	11:00
150 Left	12.6	11:00	7.9	11:00	5.8	11:00
100 Left	16.5	11:30	11.8	11:30	7.6	11:00
50 Left	20.4	11:30-12T	12.5	11:30T	8.2	11:00T
25 Left	17.1	11:30-12T	11.4	10-11T	7.3	10:00
CL	14.8	12:00	8.5	10-11T	7.3	10-11T

(Sheet 1 of 3)

Note: Data plotted in Plates 126-128.
Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.
[2]To convert from fps to m/sec multiply by 0.3048.
[3]12:00 is in the downstream direction parallel to the model center line. T indicates turbulence.

Table 47 (Continued)

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
300 ft Downstream of End Sill (3+00A) (continued)						
50 Right	6.0	11:00	4.7	11:00	4.7	11:00
400 ft Downstream of End Sill (4+00A)						
250 Left	2.6	11:00T	2.1	11:00T	1.8	11:00T
200 Left	10.1	11:00	7.9	11:00	6.9	11:00
150 Left	11.8	11:30	9.6	11:30	7.2	11:30
100 Left	15.5	11:30	10.6	11:30	8.9	11:30
50 Left	14.5	11:30	10.5	11:30	6.7	11:30
CL	10.8	11:30	9.0	11:30	4.3	12:00
50 Right	3.8	12:00	2.2	6:00	1.8	5:00
75 Right	1.9	5:00T	2.5	5:00	3.0	5:00
500 ft Downstream of End Sill (5+00A)						
300 Left	6.9	11:00	6.4	11:00	5.6	11:00
225 Left	11.4	11:00	9.7	11:30	8.2	11:30
175 Left	11.3	11:00	12.3	11:30	10.3	11:30
125 Left	15.0	11:30	12.3	11:30	9.2	11:30
75 Left	12.8	11:30	10.7	11:30	9.2	11:30
50 Left	10.3	11:30	7.6	11:30-12	7.0	11:30
25 Left	7.0	11:30-12	6.5	11:30-12	5.9	11:30-12
600 ft Downstream of End Sill (6+00A)						
275 Left	10.3	11:30	10.2	11:30	7.2	11:30
225 Left	12.5	11:30	11.4	11:30	8.7	11:30
175 Left	12.7	11:30	12.6	11:30	9.2	11:30
125 Left	13.9	11:30	12.2	11:30	11.0	11:30
100 Left	13.1	11:30	11.4	11:30	8.6	11:30
700 ft Downstream of End Sill (7+00A)						
275 Left	12.2	11:30	11.4	11:30	10.0	11:30
225 Left	13.9	11:30	12.1	11:30	9.6	11:30
175 Left	12.9	11:30	11.0	11:30	9.4	11:30
150 Left	12.2	11:30	9.6	11:30	9.1	11:30

(Sheet 2 of 3)

Table 47 (Concluded)

Distance from Center Line, ft[1]	Surface Velocity fps[2]	Direction of Flow[3]	Middepth Velocity fps[2]	Direction of Flow[3]	Bottom Velocity fps[2]	Direction of Flow[3]
800 ft Downstream of End Sill (8+00A)						
300 Left	11.2	12:00	10.7	12:00	9.3	12:00
250 Left	13.0	12:00	12.1	12:00	9.8	12:00
200 Left	12.1	12:00	10.5	12:00	9.2	12:00
175 Left	10.6	12:00	10.5	12:00	9.5	12:00

(Sheet 3 of 3)

Table 48
Wave Elevations in Exit Channel, Realigned Channel/Type 1 Stilling Basin

Distance from Center Line, ft[1]	Q_C = 356 cu m/sec (12,700 cfs) Q_R = 6 cu m/sec (200 cfs) Tailwater El 1315.0		Q_C = 591 cu m/sec (21,100 cfs) Q_R = 174 cu m/sec (6,200 cfs) Tailwater El 1320.2		Q_C = 812 cu m/sec (29,000 cfs) Q_R = 204 cu m/sec 7,300 cfs Tailwater El 1322.5		Q_C = 1,044 cu m/sec (37,300 cfs) Q_R = 812 cu m/sec (29,000 cfs) Tailwater El 1327.0	
	Max	Min	Max	Min	Max	Min	Max	Min
End Sill (0+00A)								
25 Left	1317.8	1316.4	1324.1	1322.1	1327.4	1323.7	1340.4	1333.4
CL	1317.2	1316.4	1323.3	1322.0	1327.4	1325.2	1340.4	1333.4
25 Right	1317.3	1316.2	1324.2	1322.1	1327.3	1324.9	1345.0	1335.7
200 ft Downstream of End Sill (2+00A)								
125 Left	-	-	-	-	1323.3	1323.1	1327.8	1326.7
100 Left	-	-	1320.5	1320.1	1323.7	1323.0	1327.3	1326.7
50 Left	1315.9	1315.6	1320.3	1320.0	1323.7	1323.1	1329.8	1326.9
CL	1316.0	1315.8	1320.8	1320.3	1324.1	1323.1	1332.0	1328.1
50 Right	1315.9	1315.8	1321.0	1320.5	1323.9	1323.2	1328.9	1327.6
75 Right	-	-	-	-	-	-	1330.4	1327.9
100 Right	-	-	-	-	1323.8	1323.4	-	-
250 ft Downstream of End Sill (2+50A)								
150 Left	-	-	-	-	1323.2	1322.9	1327.7	1327.1
125 Left	-	-	-	-	1323.4	1323.1	1327.9	1327.1
75 Left	1315.6	1315.5	1320.7	1320.4	1324.8	1323.7	1330.1	1327.8

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Note: Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.

Table 48 (Continued)

Distance from Center Line, ft[1]	Q_C = 356 cu m/sec (12,700 cfs) Q_R = 6 cu m/sec (200 cfs) Tailwater El 1315.0		Q_C = 591 cu m/sec (21,100 cfs) Q_R = 174 cu m/sec (6,200 cfs) Tailwater El 1320.2		Q_C = 812 cu m/sec (29,000 cfs) Q_R = 204 cu m/sec 7,300 cfs Tailwater El 1322.5		Q_C = 1,044 cu m/sec (37,300 cfs) Q_R = 812 cu m/sec (29,000 cfs) Tailwater El 1327.0	
	Max	Min	Max	Min	Max	Min	Max	Min
250 ft Downstream of End Sill (2+50A)								
25 Left	1315.6	1315.6	1320.7	1320.3	1323.5	1323.1	1330.8	1327.3
25 Right	1315.9	1315.6	1320.8	1320.4	1323.5	1323.1	1329.3	1327.6
50 Right	1315.9	1315.7	-	-	-	-	-	-
75 Right	-	-	-	-	1323.5	1323.2	1329.7	1328.5
300 ft Downstream of End Sill (3+00A)								
175 Left	-	-	-	-	-	-	1327.6	1327.1
150 Left	-	-	-	-	1323.4	1323.1	1328.2	1327.3
125 Left	-	-	-	-	1323.7	1323.2	-	-
100 Left	1315.5	1315.4	1320.7	1320.4	-	-	1328.8	1327.5
75 Left	-	-	-	-	1324.3	1323.2	-	-
50 Left	1315.8	1315.5	1320.9	1320.5	-	-	1329.4	1325.9
25 Left	1315.9	1315.6	1320.9	1320.6	1323.9	1323.2	1328.9	1326.6
CL	1316.0	1315.6	1320.7	1320.5	1324.1	1323.6	1328.7	1327.5
25 Right	-	-	-	-	1323.3	1323.3	-	-
50 Right	-	-	-	-	-	-	1328.5	1327.3
75 Right	-	-	-	-	1323.3	1323.0	-	-

(Sheet 2 of 4)

Table 48 (Continued)

Distance from Center Line, ft[1]	Q_C = 356 cu m/sec (12,700 cfs) Q_R = 6 cu m/sec (200 cfs) Tailwater El 1315.0		Q_C = 591 cu m/sec (21,100 cfs) Q_R = 174 cu m/sec (6,200 cfs) Tailwater El 1320.2		Q_C = 812 cu m/sec (29,000 cfs) Q_R = 204 cu m/sec 7,300 cfs Tailwater El 1322.5		Q_C = 1,044 cu m/sec (37,300 cfs) Q_R = 812 cu m/sec (29,000 cfs) Tailwater El 1327.0	
	Max	Min	Max	Min	Max	Min	Max	Min
400 ft Downstream of End Sill (4+00A)								
250 Left	-	-	-	-	1322.4	1322.3	1327.8	1327.3
200 Left	-	-	-	-	1322.4	1322.3	1328.1	1327.8
150 Left	-	-	-	-	1323.2	1322.4	1328.6	1327.5
100 Left	-	-	-	-	1323.9	1322.9	1329.0	1327.6
50 Left	-	-	-	-	1323.7	1323.0	1329.0	1328.1
CL	-	-	-	-	1323.7	1323.3	1329.1	1328.1
50 Right	-	-	-	-	1323.5	1323.3	1328.9	1328.1
75 Right	-	-	-	-	1324.0	1323.5	1328.7	1328.2
500 ft Downstream of End Sill (5+00A)								
300 Left	-	-	-	-	1322.1	1321.8	1329.5	1328.8
275 Left	-	-	-	-	1322.1	1322.0	-	-
225 Left	-	-	-	-	1322.7	1322.6	1328.8	1328.5
175 Left	-	-	-	-	1323.2	1322.6	1328.5	1328.1
125 Left	-	-	-	-	1323.2	1322.9	1328.5	1327.4
75 Left	-	-	-	-	1323.7	1323.3	1328.3	1327.4
50 Left	-	-	-	-	1323.8	1323.5	1327.8	1327.4
25 Left	-	-	-	-	1324.2	1323.7	1327.4	1327.2

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Table 48 (Concluded)

Distance from Center Line, ft[1]	Q_C = 356 cu m/sec (12,700 cfs) Q_R = 6 cu m/sec (200 cfs) Tailwater El 1315.0		Q_C = 591 cu m/sec (21,100 cfs) Q_R = 174 cu m/sec (6,200 cfs) Tailwater El 1320.2		Q_C = 812 cu m/sec (29,000 cfs) Q_R = 204 cu m/sec 7,300 cfs Tailwater El 1322.5		Q_C = 1,044 cu m/sec (37,300 cfs) Q_R = 812 cu m/sec (29,000 cfs) Tailwater El 1327.0	
	Max	Min	Max	Min	Max	Min	Max	Min
600 ft Downstream of End Sill (6+00A)								
275 Left	-	-	-	-	1322.4	1322.2	1327.6	1327.2
225 Left	-	-	-	-	1322.9	1322.5	1328.5	1327.2
175 Left	-	-	-	-	1322.5	1322.4	1328.0	1327.3
125 Left	-	-	-	-	1322.5	1322.4	1327.6	1327.3
100 Left	-	-	-	-	1322.6	1322.4	1328.0	1327.6
700 ft Downstream of End Sill (7+00A)								
275 Left	-	-	-	-	1322.9	1322.5	1327.8	1327.2
225 Left	-	-	-	-	1322.9	1322.3	1327.6	1327.2
175 Left	-	-	-	-	1323.0	1322.7	1327.6	1327.0
150 Left					1322.7	1322.3	1327.7	1327.2
800 ft Downstream of End Sill (8+00A)								
300 Left					1322.6	1322.3	1327.5	1327.0
250 Left					1322.6	1322.4	1327.4	1327.0
200 Left					1322.6	1322.4	1327.2	1326.8
175 Left	-	-	-	-	1322.5	1322.4	1327.2	1326.6

(Sheet 4 of 4)

Table 49
Center Line Wave Elevations in Exit Channel, Realigned Channel Configuration/Type 1 Stilling Basin

Distance Downstream of End Sill, ft[1]	Q_C = 591 cu m/sec (21,100 cfs) Q_R = 174 cu m/sec (6,200 cfs) Tailwater El 1320.2		Q_C = 812 cu m/sec (29,000 cfs) Q_R = 204 cu m/sec (7,300 cfs) Tailwater El 1322.5		Q_C = 1,044 cu m/sec (37,300 cfs) Q_R = 812 cu m/sec (29,000 cfs) Tailwater El 1327.0	
	Max	Min	Max	Min	Max	Min
50	1322.2	1321.5	1325.9	1324.9	1327.1	1324.4
100	1321.8	1321.3	1325.1	1323.8	1336.8	1331.2
150	-	-	1324.3	1323.5	-	-
200	1320.8	1320.3	1324.1	1323.1	1332.0	1328.1
250	1320.8	1320.4	1323.5	1323.1	1329.4	1327.8
300	1320.7	1320.5	1324.1	1323.6	1328.7	1327.5
350	-	-	1324.0	1323.2	-	-
400	-	-	1324.7	1324.0	-	-

Note: Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1]To convert from ft to m multiply by 0.3048.

Table 50
Water-Surface Elevations,Type 1 Basin with Stilling Basin Walls Raised to Confine Flow in Basin

Distance from Center Line, ft[1]	Q_C = 1,044 cu m/sec (37,300 cfs) Q_R = 812 cu m/sec (29,000 cfs) Tailwater El 1327.0		Q_C = 812 cu m/sec (29,000 cfs) Q_R = 204 cu m/sec (7,300 cfs) Tailwater El 1322.5	
	Max	Min	Max	Min
Sta 11+50				
21 Left	1341.2	1331.5	1333.0	1327.0
CL	1346.9	1333.0	1330.3	1324.6
21 Right	1346.9	1338.9	1338.5	1327.1
End Sill				
21 Left	1341.2	1331.4	1326.2	1324.0
CL	1344.4	1335.1	1328.4	1325.5
21 Right	1339.3	1330.1	1328.3	1324.4

Note: Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1] To convert from ft to m multiply by 0.3048.

Table 51
Water-Surface Elevations, Type 1 Basin Without Stilling Basin Walls Raised to Confine Flow in Basin

Distance from Center Line, ft[1]	Q_C = 1,044 cu m/sec (37,300 cfs Q_R = 812 cu m/sec (29,000 cfs) Tailwater Elevation 1327.0		Q_C = 812 cu m/sec (29,000 cfs) Q_R = 204 cu m/sec (7,300 cfs) Tailwater Elevation 1322.5	
	Max	Min	Max	Min
Sta 11+50				
21 Left	1340.6	1332.3	1331.8	1327.5
CL	1346.9	1335.0	1331.0	1323.7
21 Right	1345.9	1340.2	1337.7	1330.5
End Sill				
21 Left	1344.5	1332.1	1327.9	1322.5
CL	1345.3	1334.3	1327.9	1325.6
21 Right	1345.3	1333.9	1327.3	1325.2

Note: Q_C = chute discharge; Q_R = Big Sioux River discharge.
[1] To convert from ft to m multiply by 0.3048.

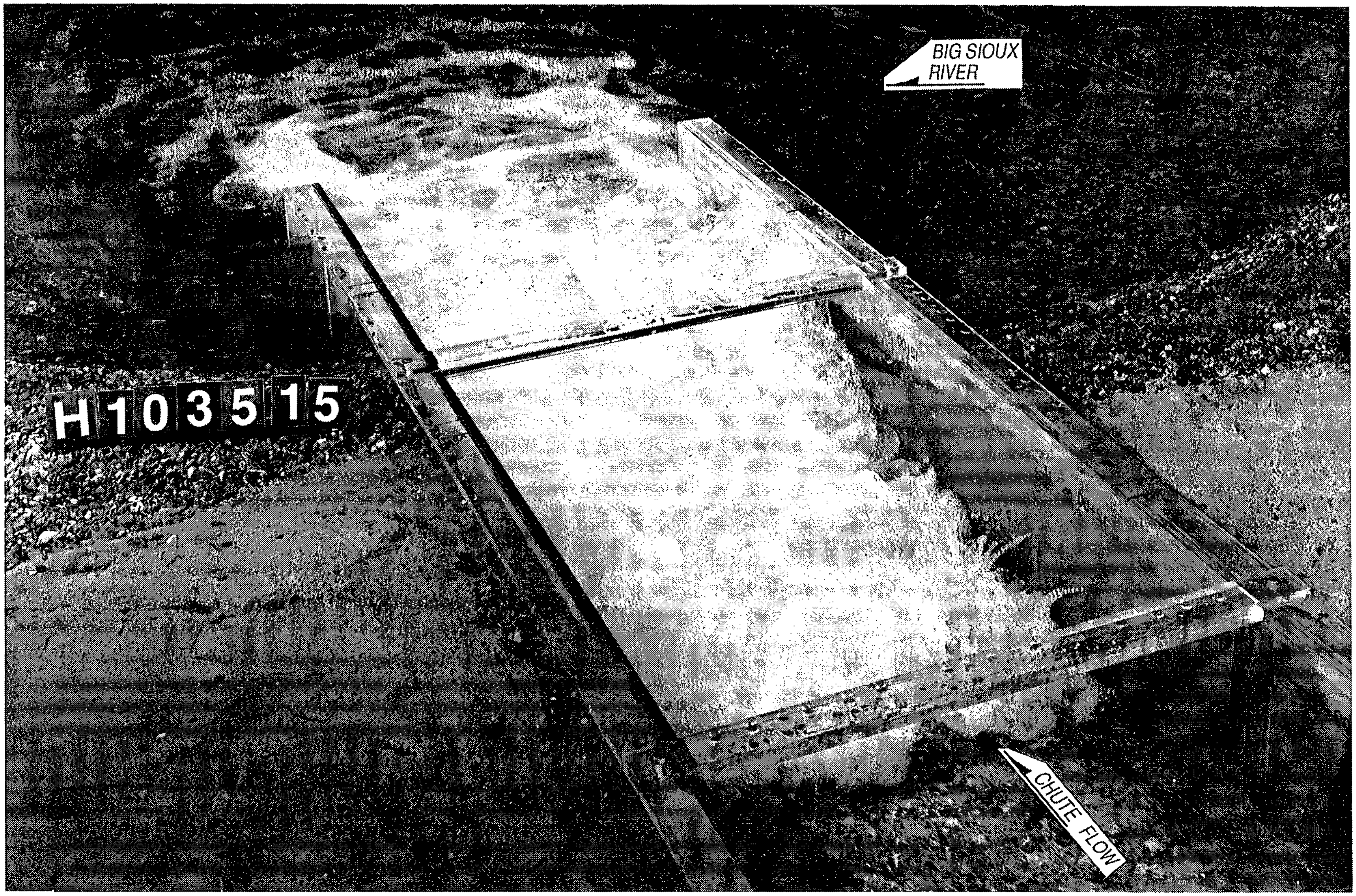


Photo 1. Type 1 stilling basin; 50-year flood; Q_C 591 cu m/sec (21,100 cfs); Q_R 174 cu m/sec (6,200 cfs); tailwater el 1320.2

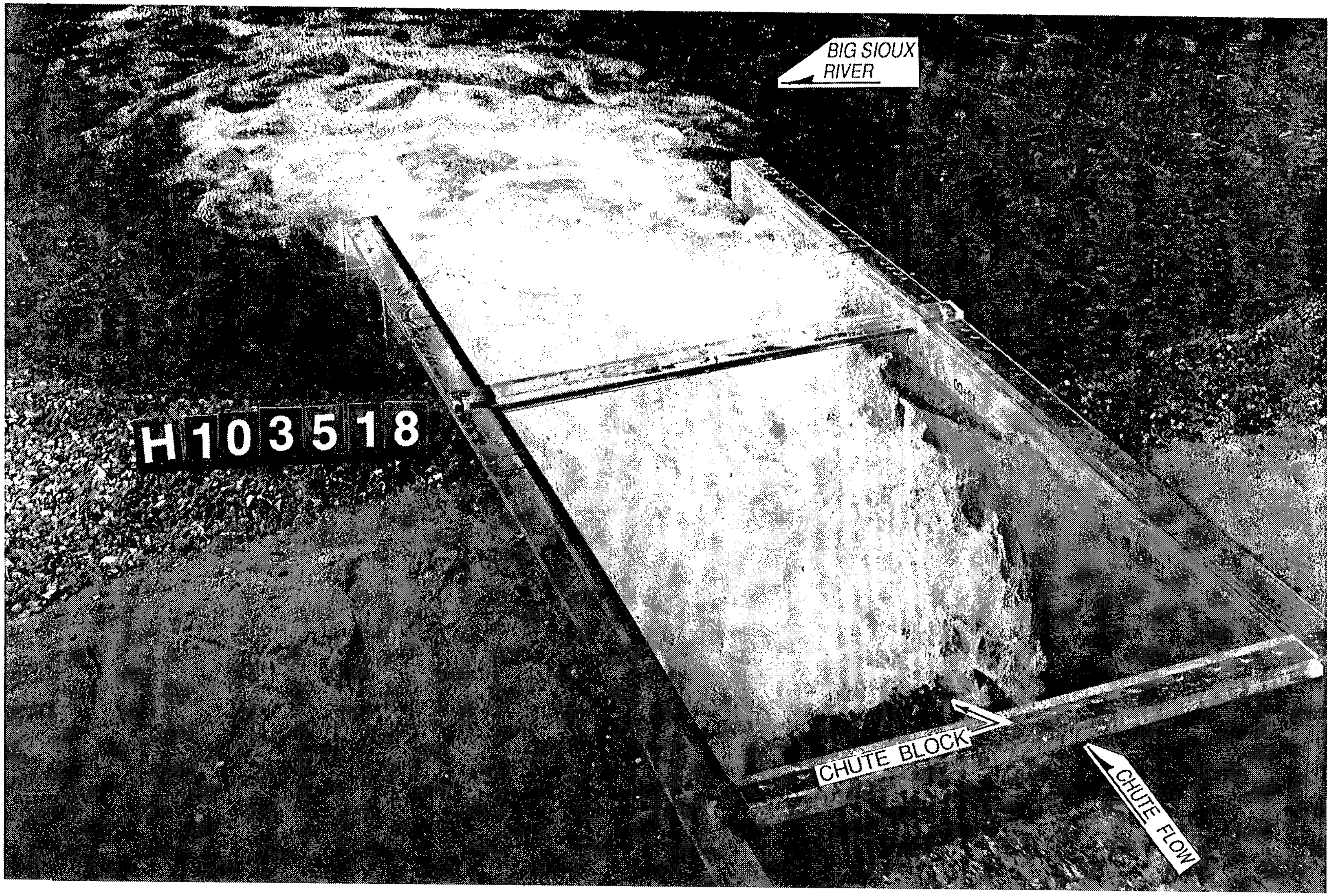


Photo 2. Type 1 stilling basin; 1969 flood; Q_C 812 cu m/sec (29,000 cfs); Q_R 316 cu m/sec (11,300 cfs); tailwater el 1324.5

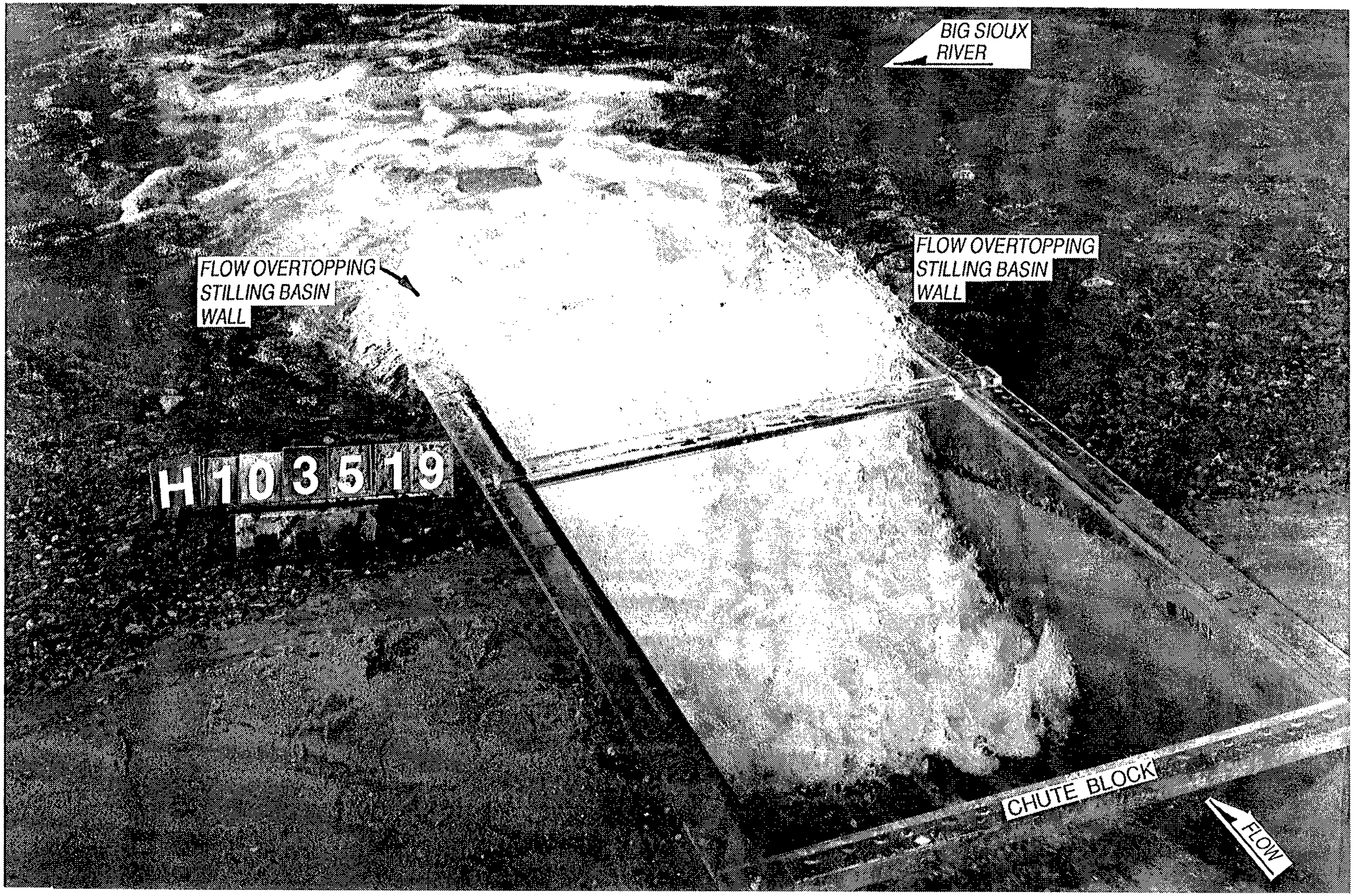


Photo 3. Type 1 stilling basin; 500-year flood; Q_C 1,044 cu m/sec (37,300 cfs); Q_R 812 cu m/sec (29,000 cfs); tailwater el 1327.0

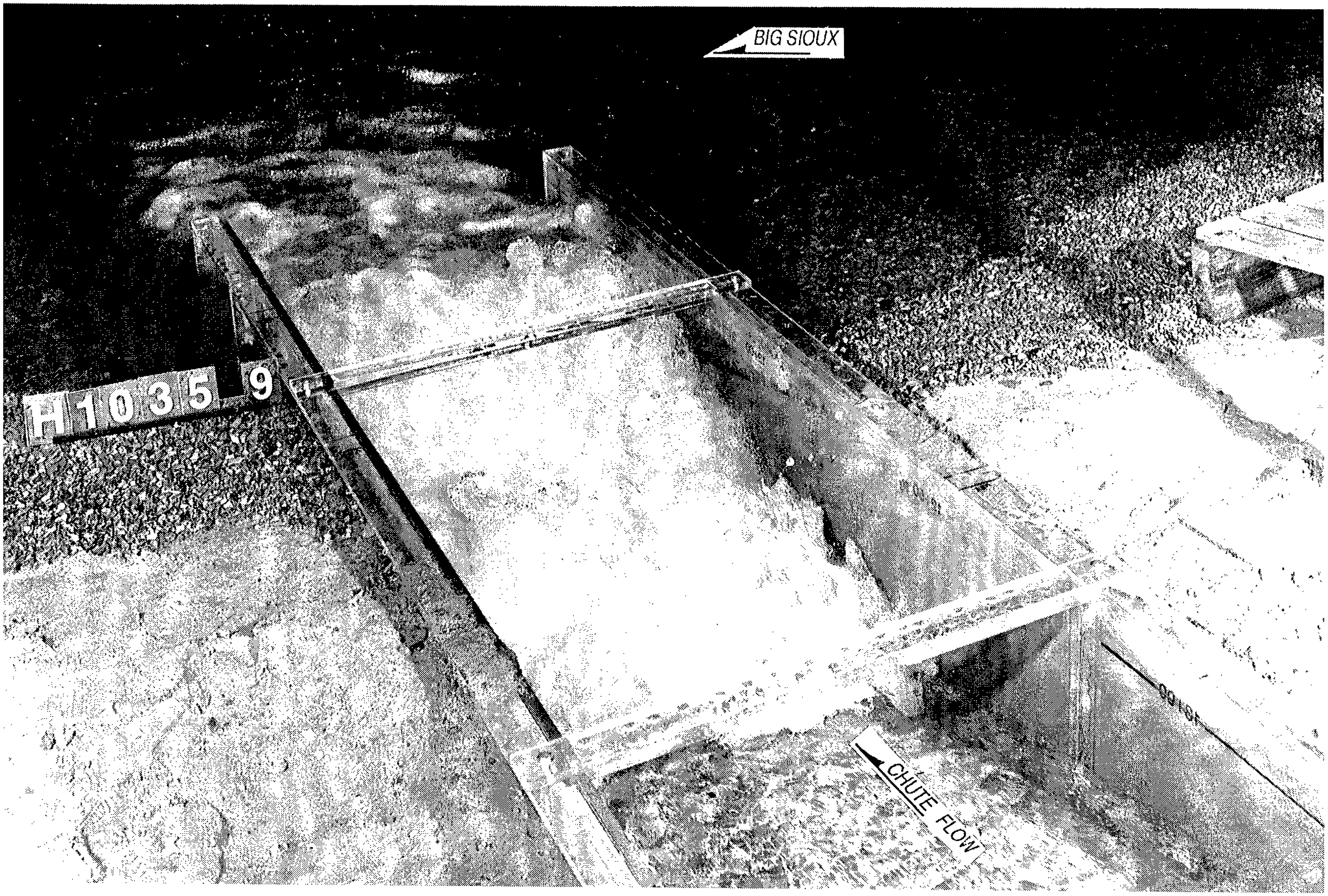


Photo 4. Type 2 stilling basin; 50-year flood; Q_C 591 cu m/sec (21,100 cfs); Q_R 174 cu m/sec (6,200 cfs); tailwater el 1320.2

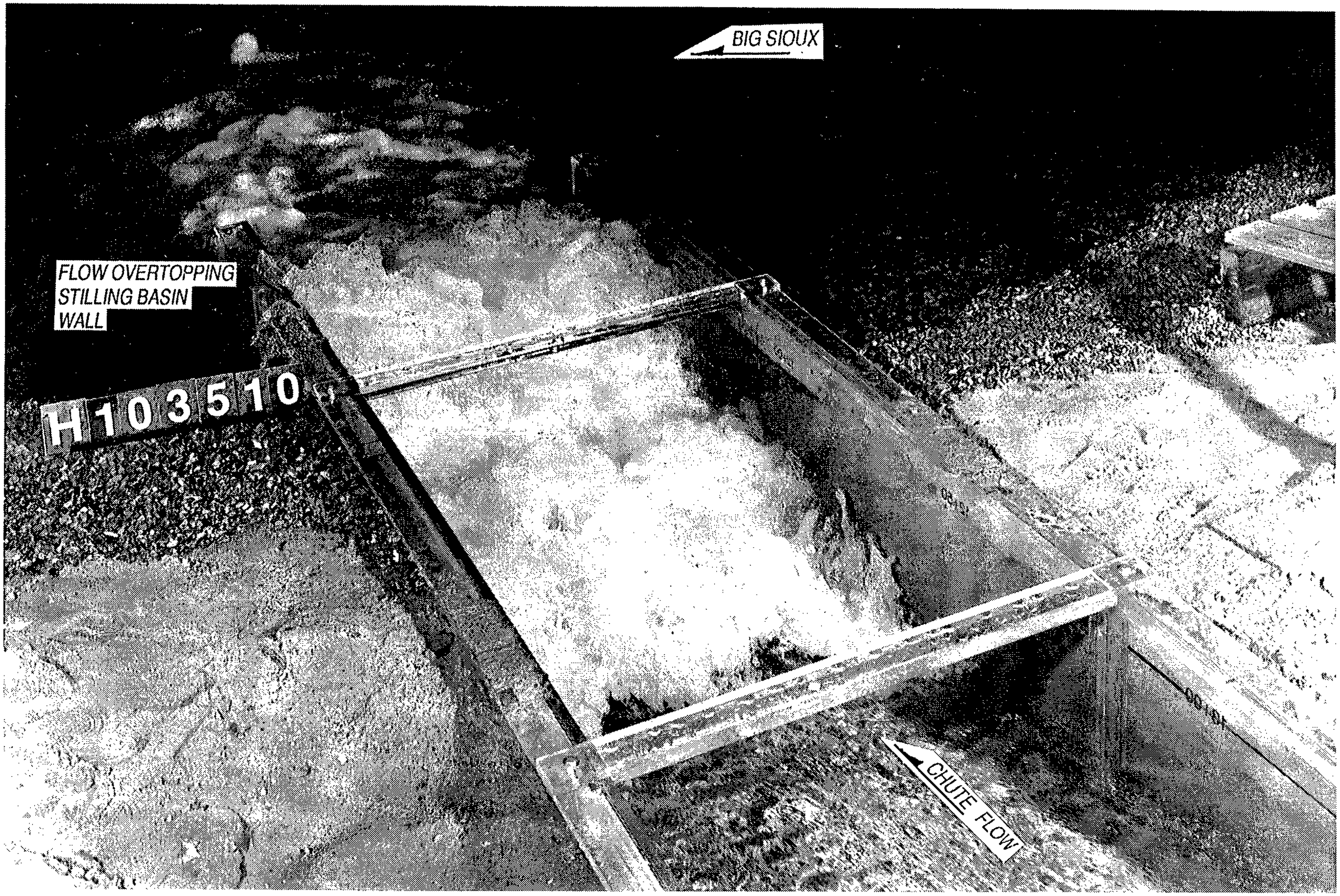


Photo 5. Type 2 stilling basin; 1969 flood; Q_C 812 cu m/sec (29,000 cfs); Q_R 316 cu m/sec (11,300 cfs); tailwater el 1324.5

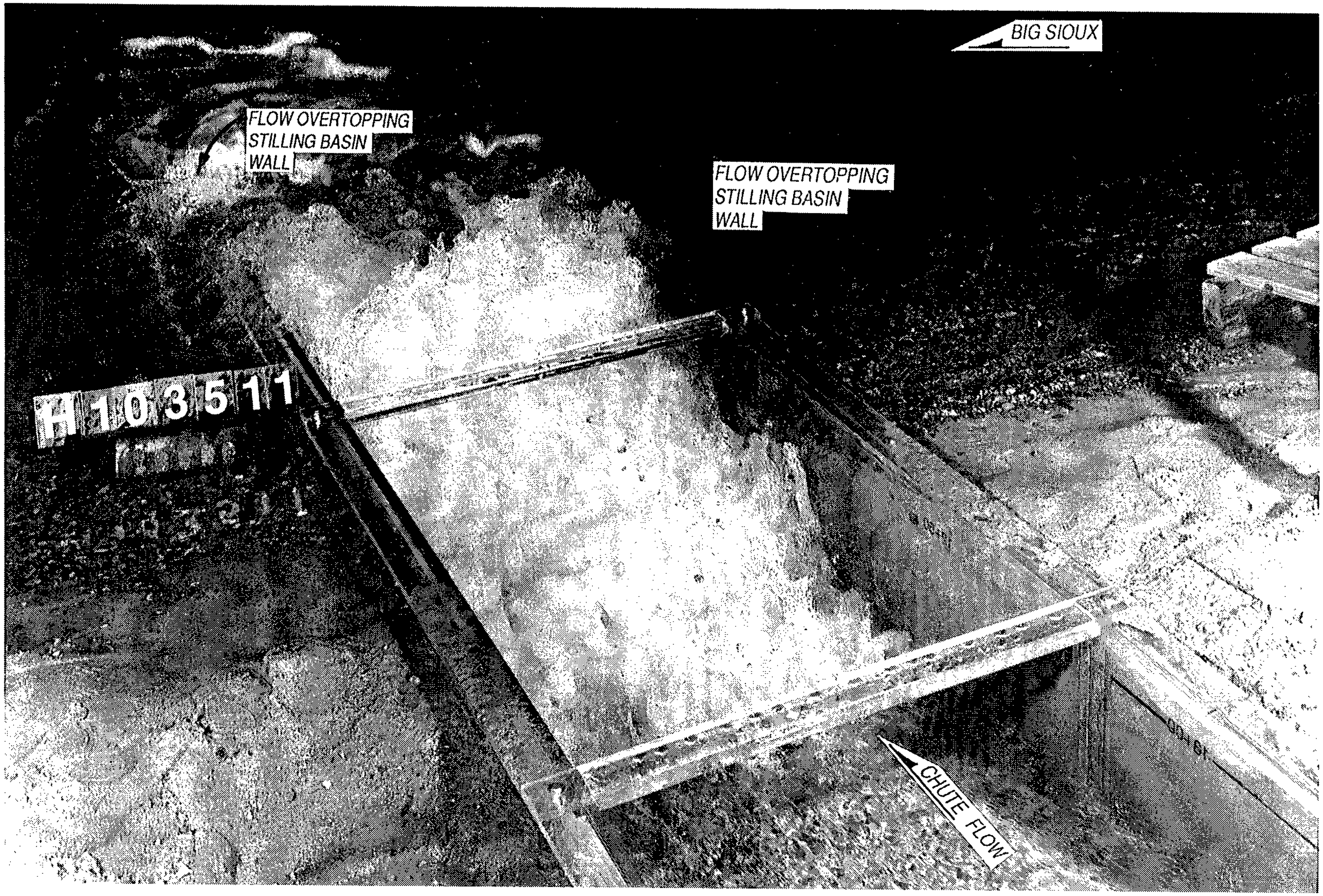


Photo 6. Type 2 stilling basin; 500-year flood; Q_C 1,044 cu m/sec (37,300 cfs); Q_R 812 cu m/sec (29,000 cfs); tailwater el 1327.0

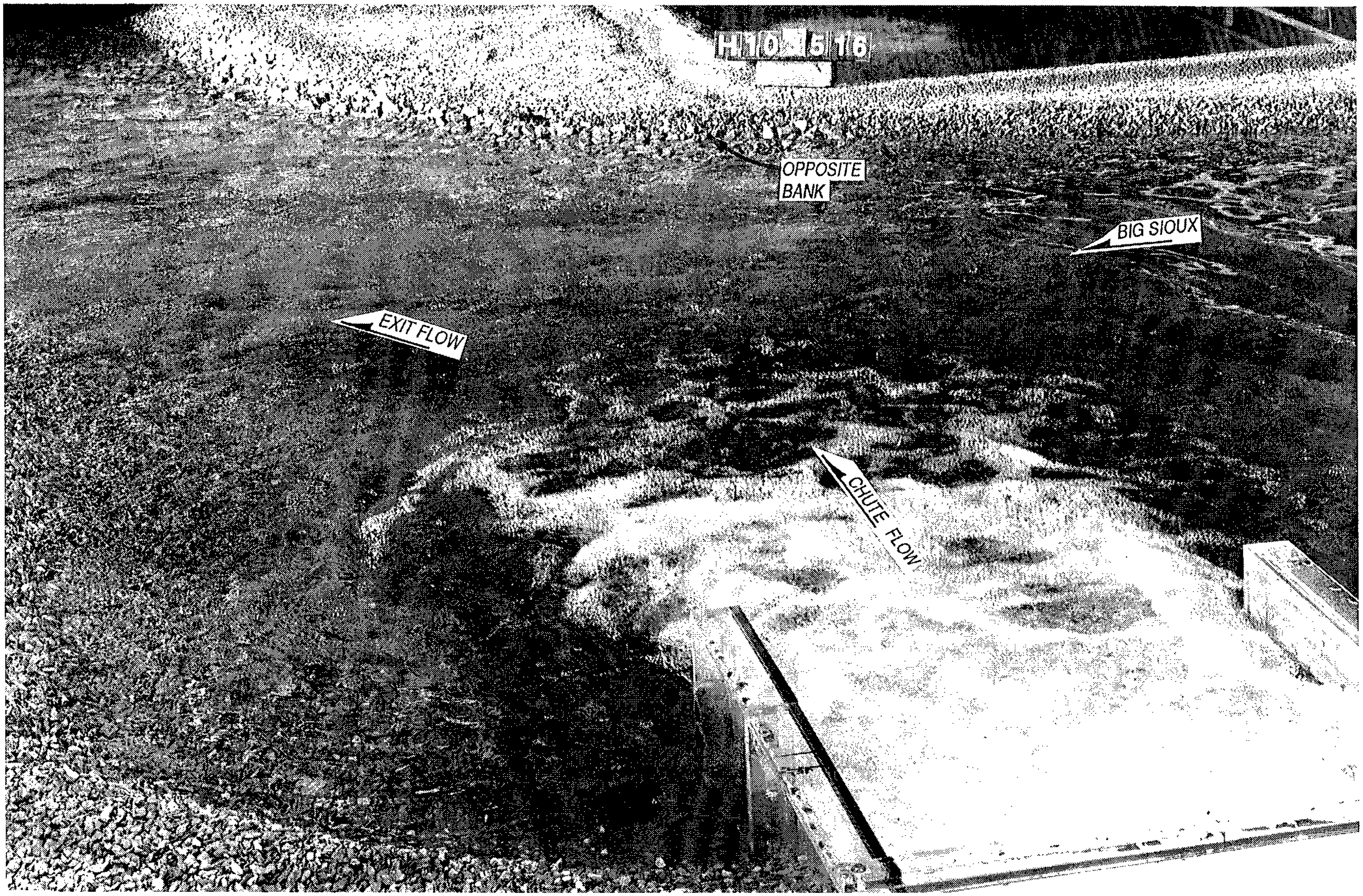


Photo 7. Type 1 stilling basin exit flow; 50-year flood; Q_C 591 cu m/sec (21,100 cfs); Q_R 174 cu m/sec (6,200 cfs); tailwater el 1320.2

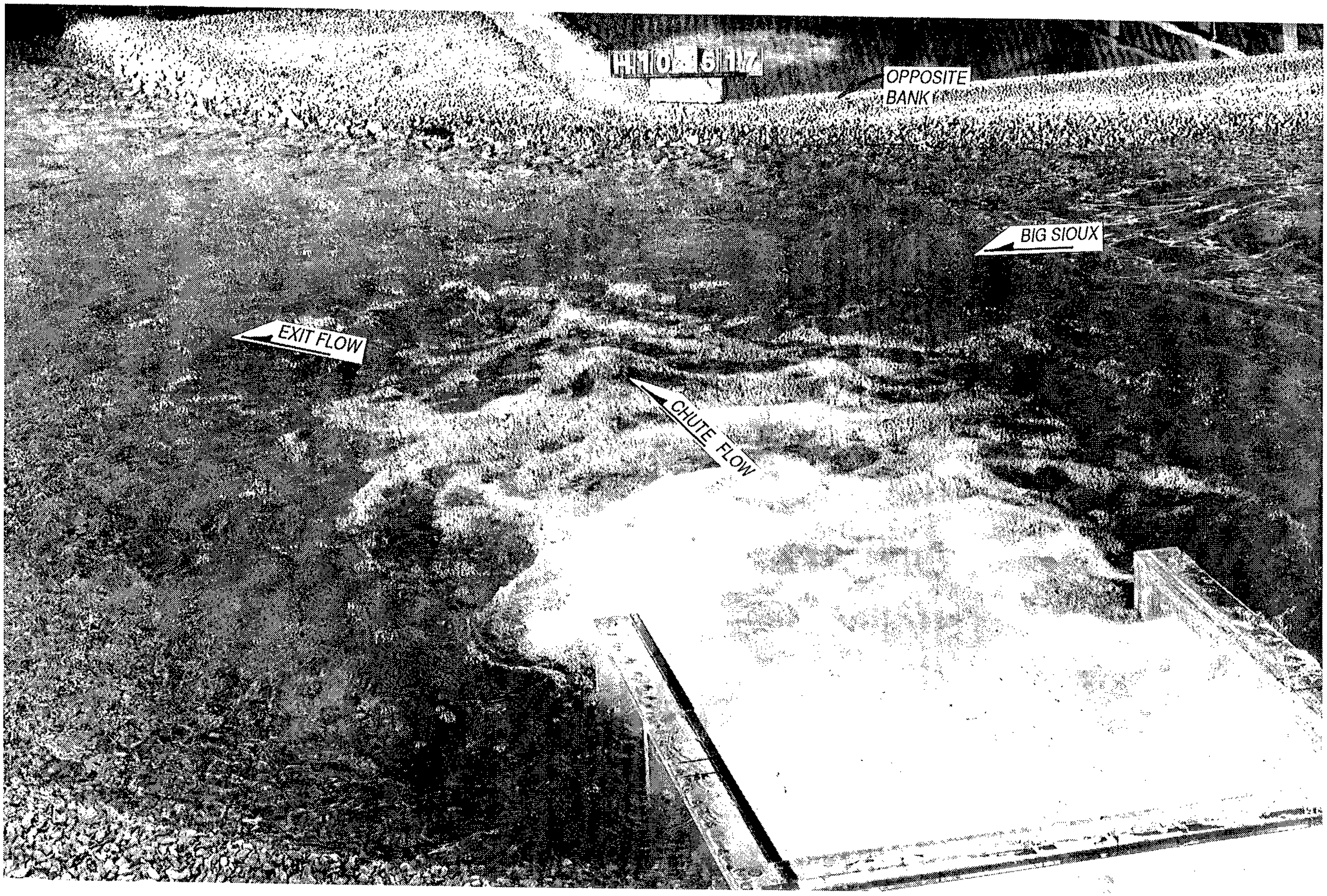


Photo 8. Type 1 stilling basin exit flow; 1969 flood; Q_C 812 cu m/sec (29,000 cfs); Q_R 316 cu m/sec (11,300 cfs); tailwater el 1324.5

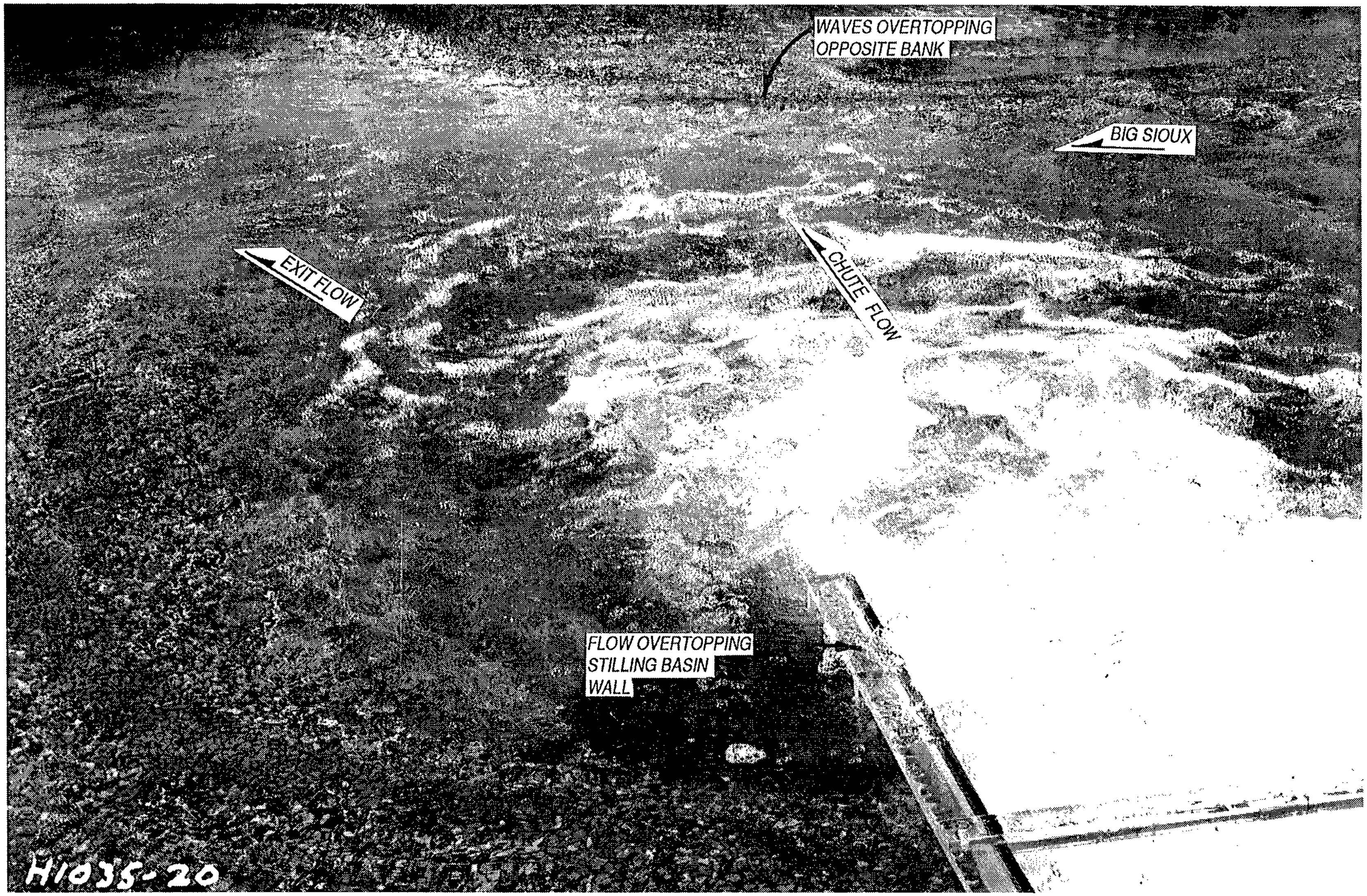


Photo 9. Type 1 stilling basin exit flow; 500-year flood; Q_C 1,044 cu m/sec (37,300 cfs); Q_R 812 cu m/sec (29,000 cfs); tailwater el 1327.0

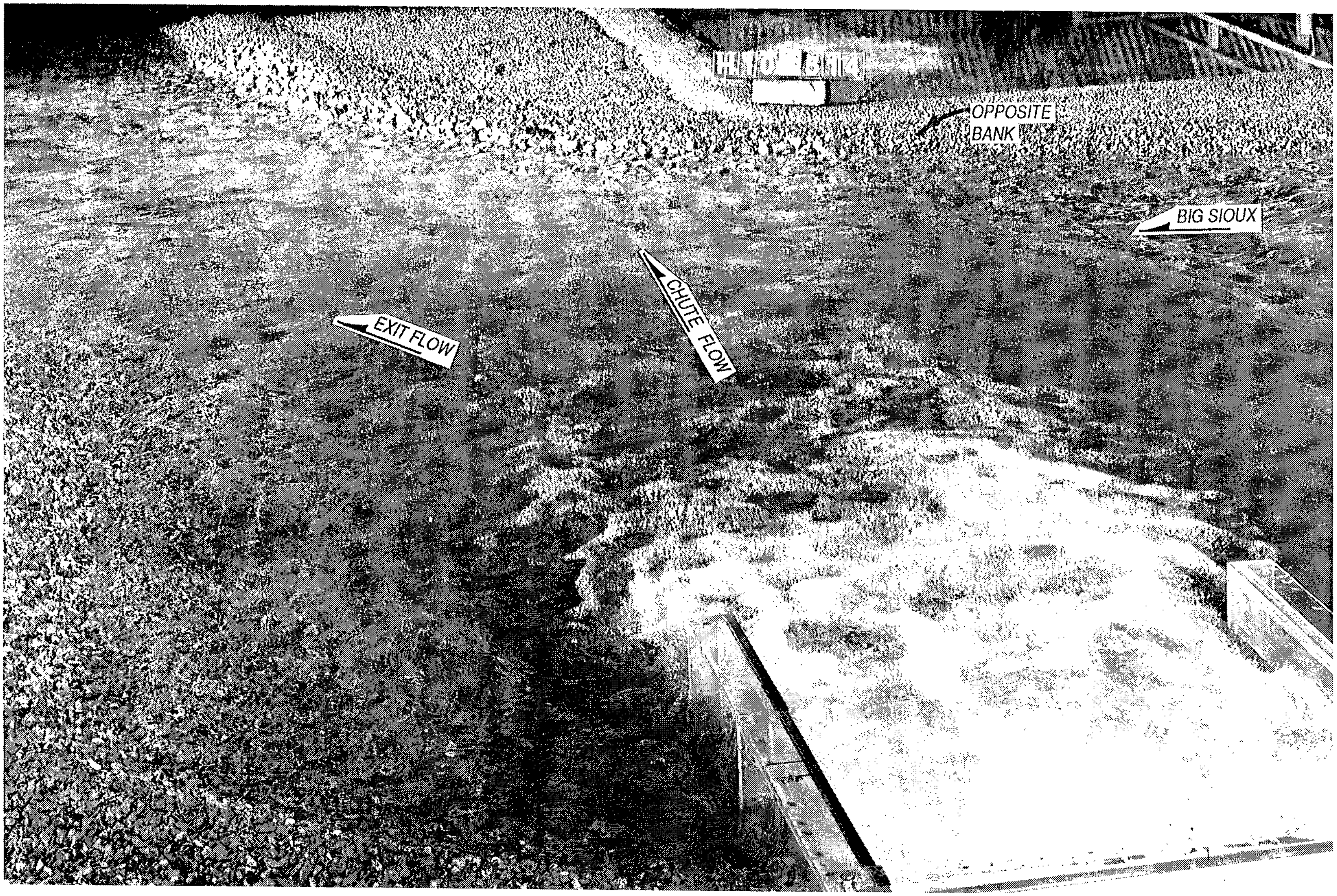


Photo 10. Type 2 stilling basin exit flow; 50-year flood; Q_C 591 cu m/sec (21,100 cfs); Q_R 174 cu m/sec (6,200 cfs); tailwater el 1320.2

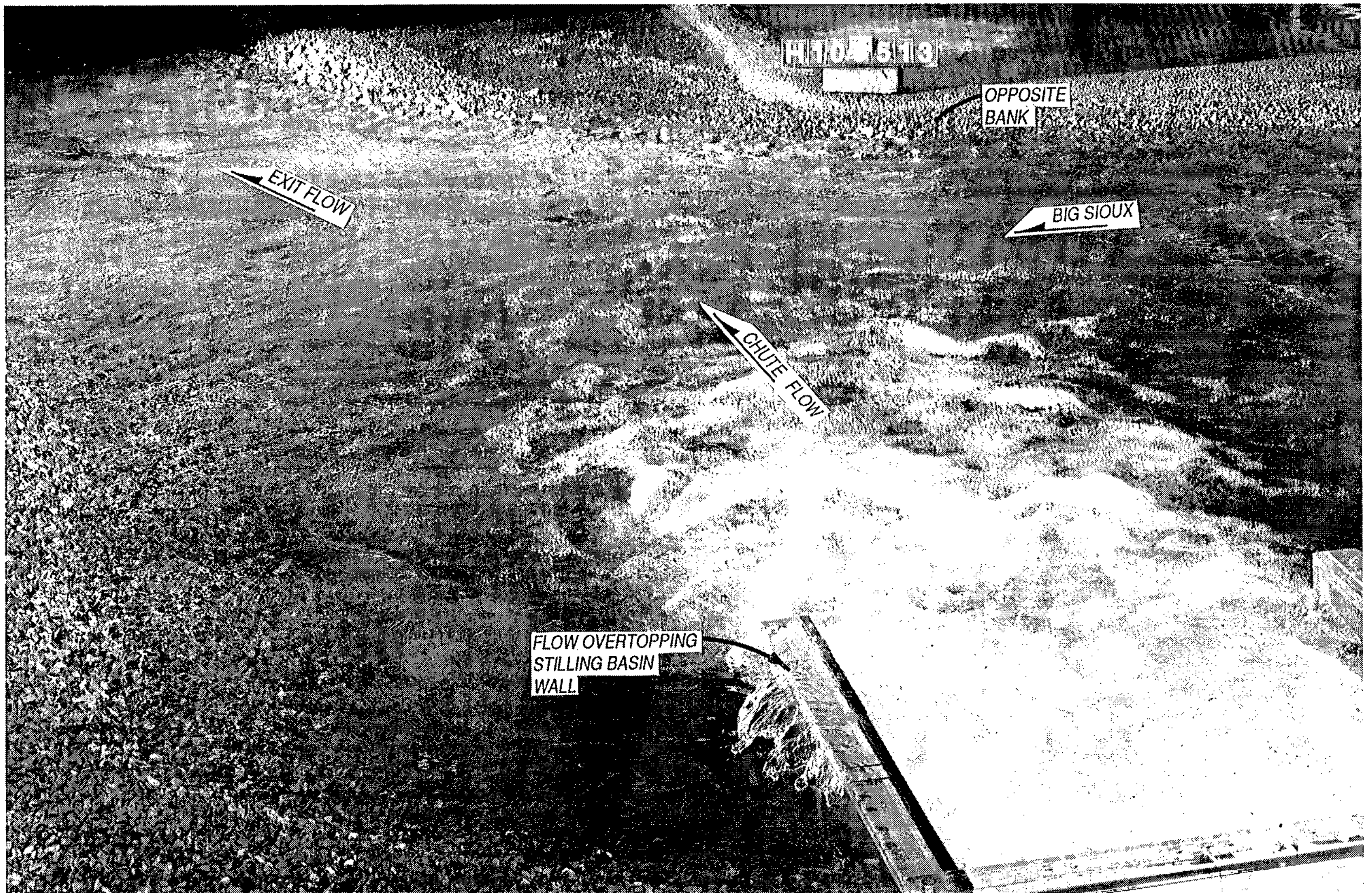


Photo 11. Type 2 stilling basin; 1969 flood; Q_C 812 cu m/sec (29,000 cfs); Q_R 316 cu m/sec (11,300 cfs); tailwater el 1324.5

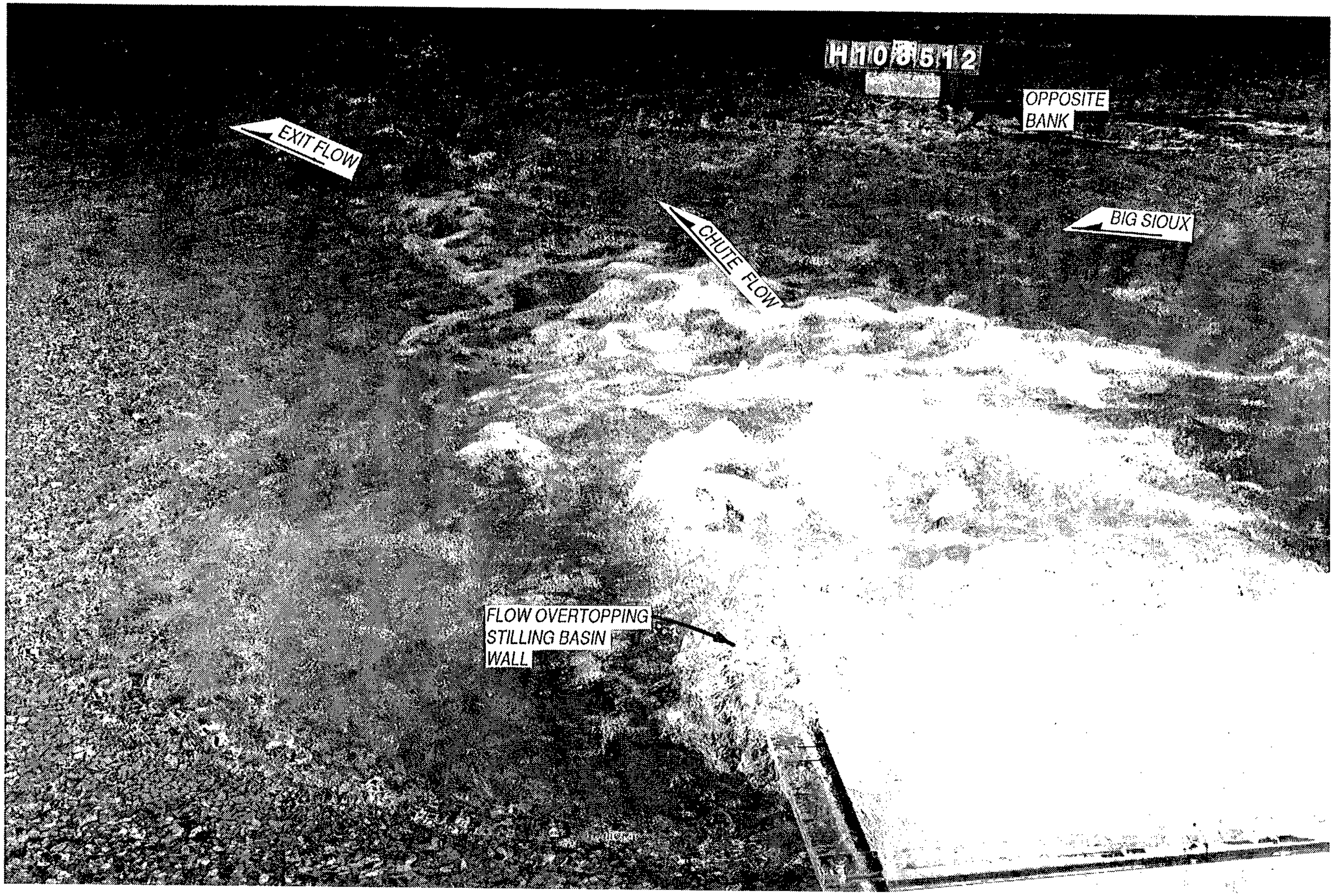


Photo 12. Type 2 stilling basin exit flow; 500-year flood; Q_C 1,044 cu m/sec (37,300 cfs); Q_R 812 cu m/sec (29,000 cfs); tailwater el 1327.0

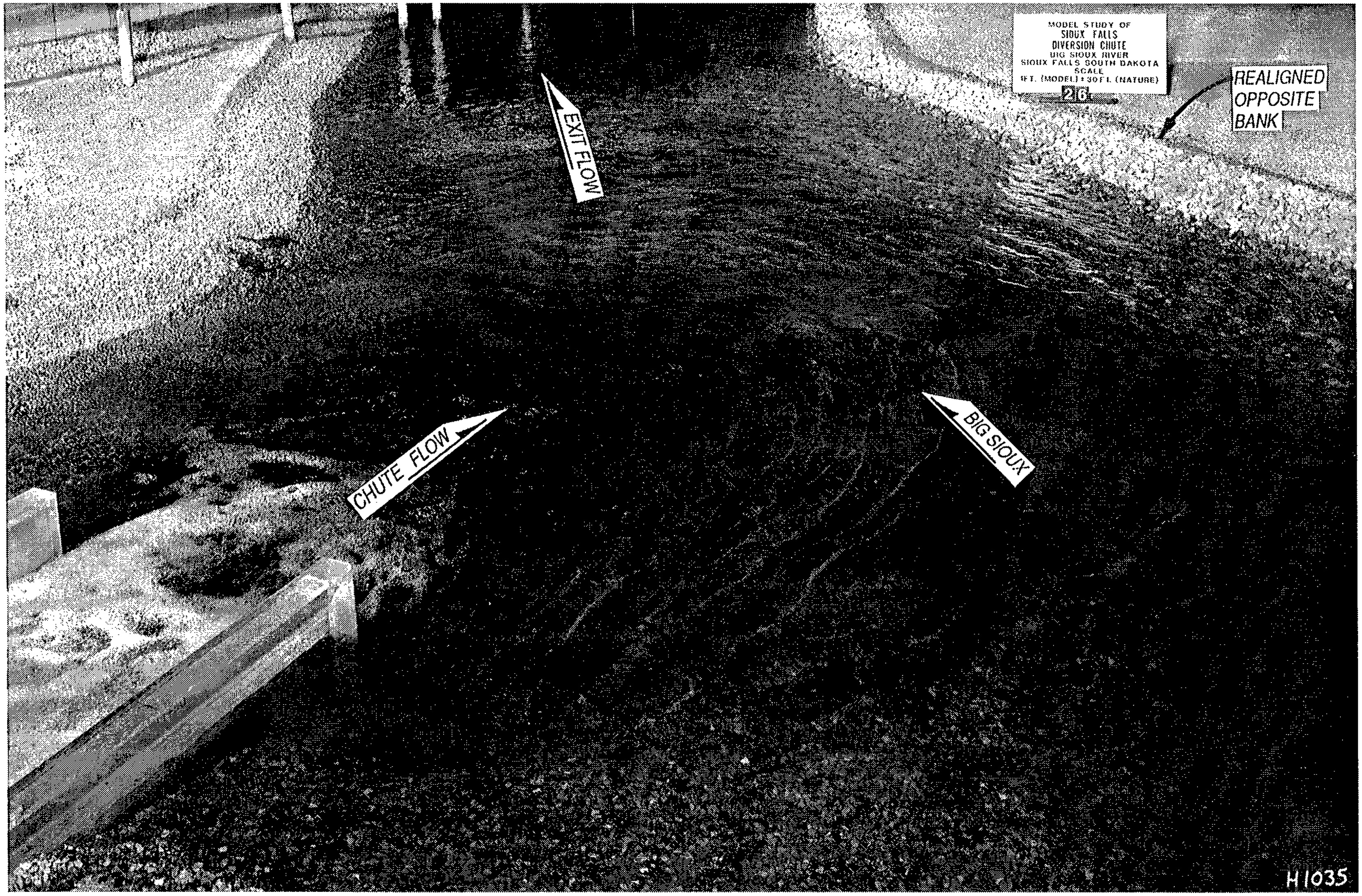


Photo 13. Realigned channel; type 1 stilling basin; 10-year flood; Q_C 356 cu m/sec (12,700 cfs); Q_R 6 cu m/sec (200 cfs); tailwater el 1315.0

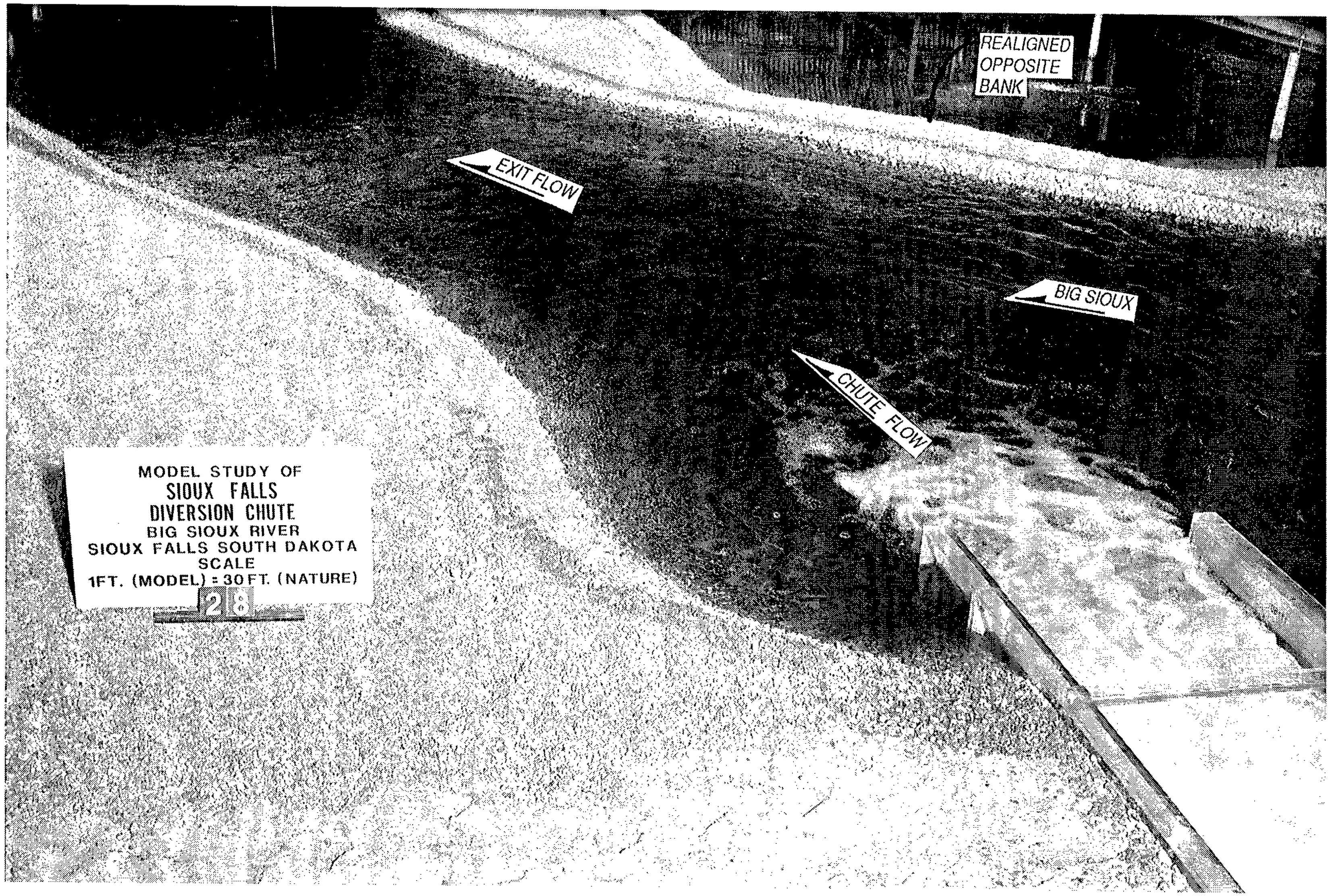


Photo 14. Realigned channel; type 1 stilling basin; 50-year flood; Q_C 591 cu m/sec (21,100 cfs); Q_R 174 cu m/sec (6,200 cfs); tailwater el 1320.2

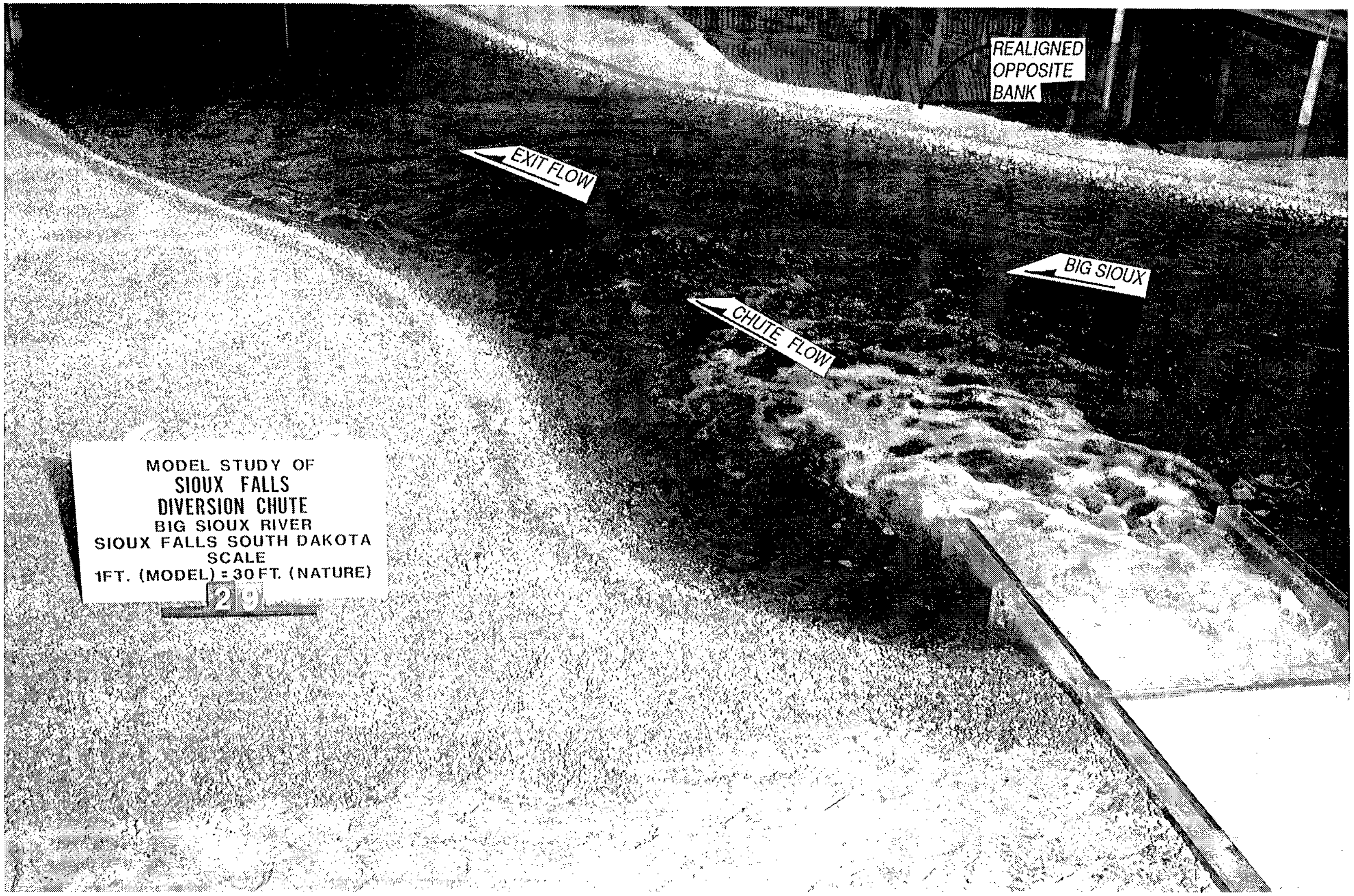


Photo 15. Realigned channel; type 1 stilling basin; 1969 flood; Q_C 812 cu m/sec (29,000 cfs); Q_R 316 cu m/sec (11,300 cfs); tailwater el 1324.5

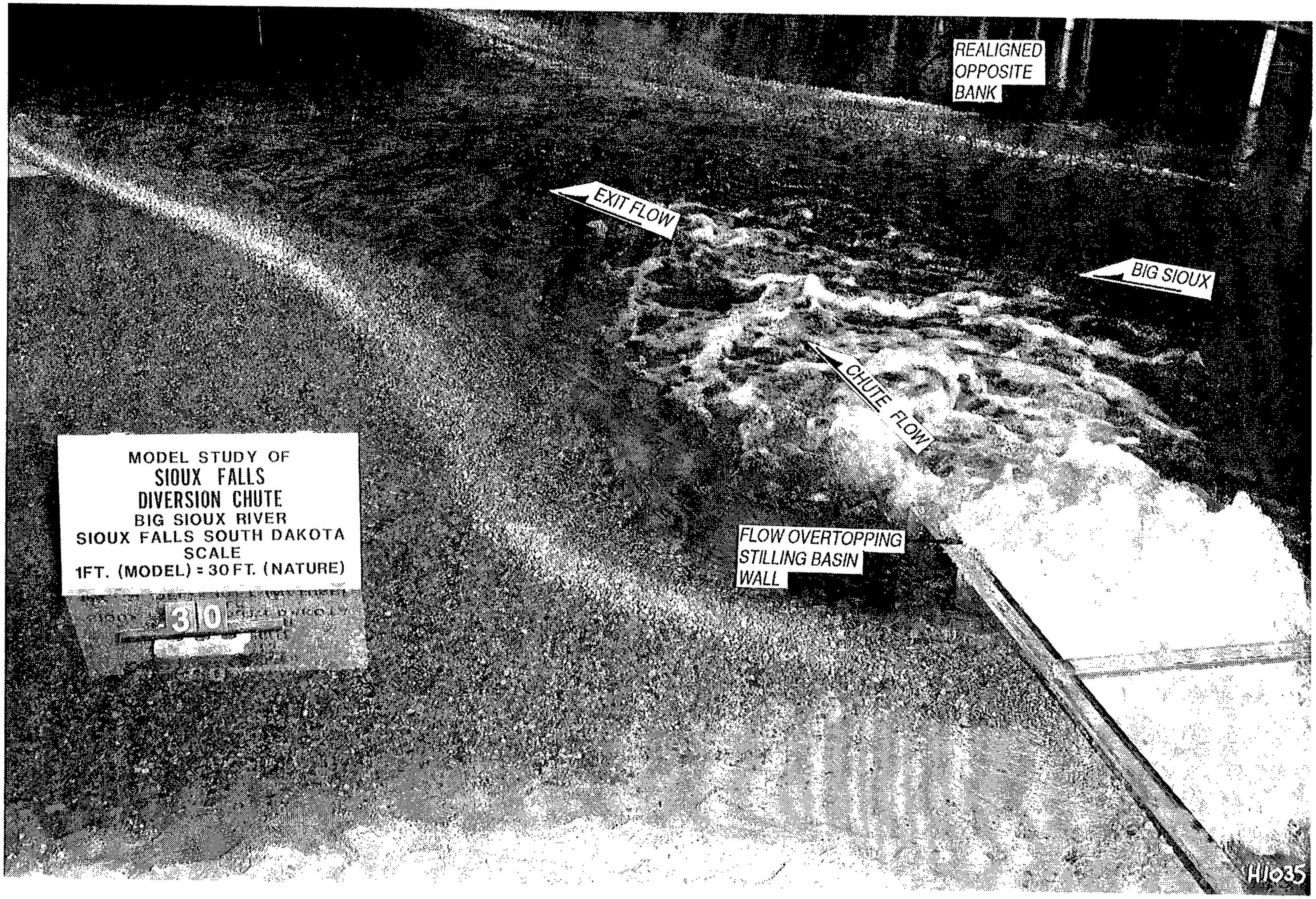
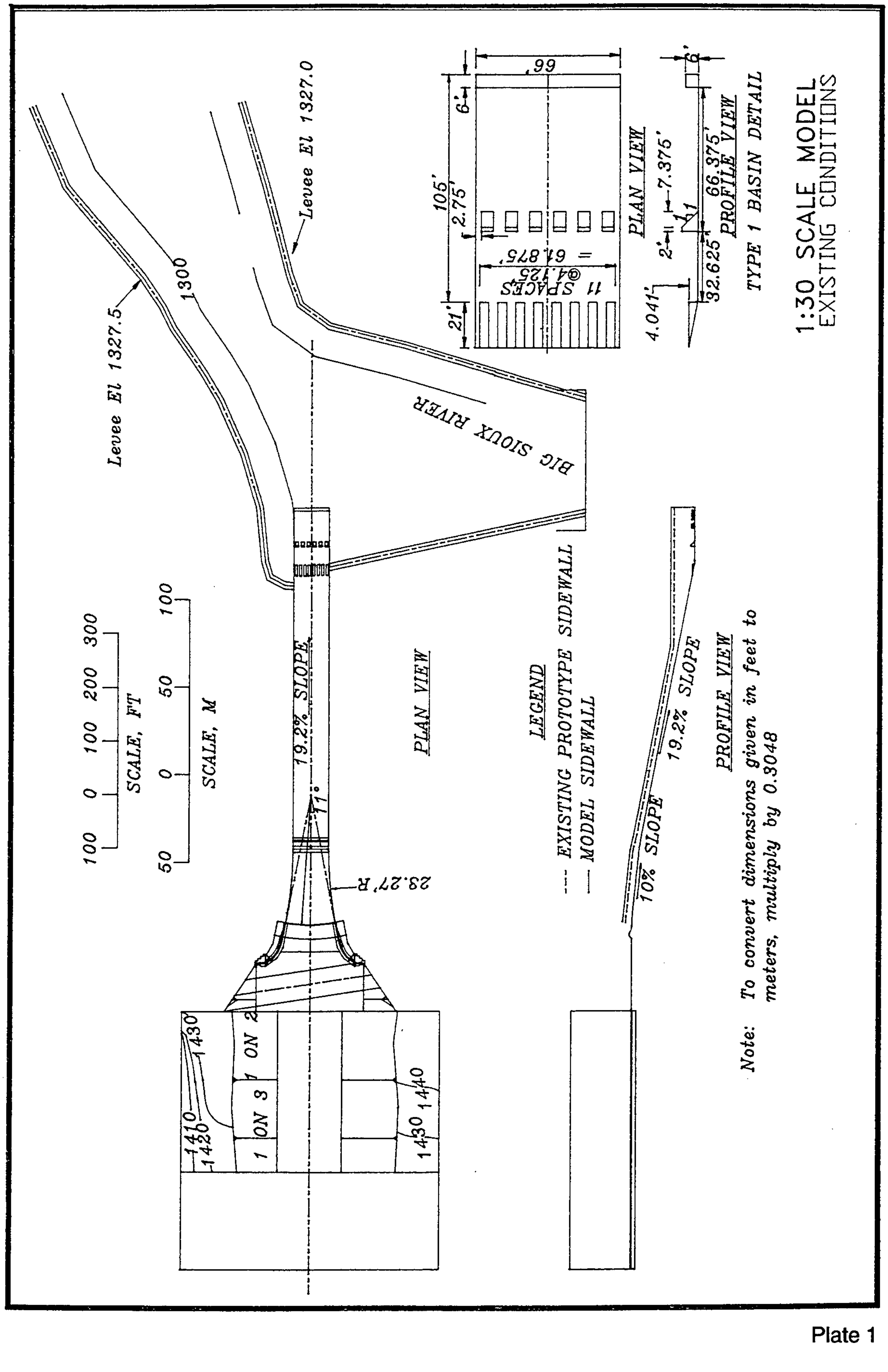


Photo 16. Realigned channel; type 1 stilling basin; 500-year flood; Q_C 1,044 cu m/sec (37,300 cfs); Q_R 812 cu m/sec (29,000 cfs); tailwater el 1327.0



1:30 SCALE MODEL
EXISTING CONDITIONS
Levee El 1327.5
Levee El 1327.0
1300
BIG SIOUX RIVER
SCALE, FT
100 0 100 200 300
SCALE, M
50 0 50 100
19.2% SLOPE
11°
23.27'R
PLAN VIEW
LEGEND
EXISTING PROTOTYPE SIDEWALL
MODEL SIDEWALL
10% SLOPE
19.2% SLOPE
PROFILE VIEW
1 ON 3
1 ON 2
1410
1420
1430
1430
1440
66'
6'
105'
2.75'
11 SPACES @4.125' = 61.875'
21'
PLAN VIEW
4.041'
2'
7.375'
1
1
32.625'
66.375'
6'
PROFILE VIEW
TYPE 1 BASIN DETAIL
Note: To convert dimensions given in feet to meters, multiply by 0.3048

Plate 1

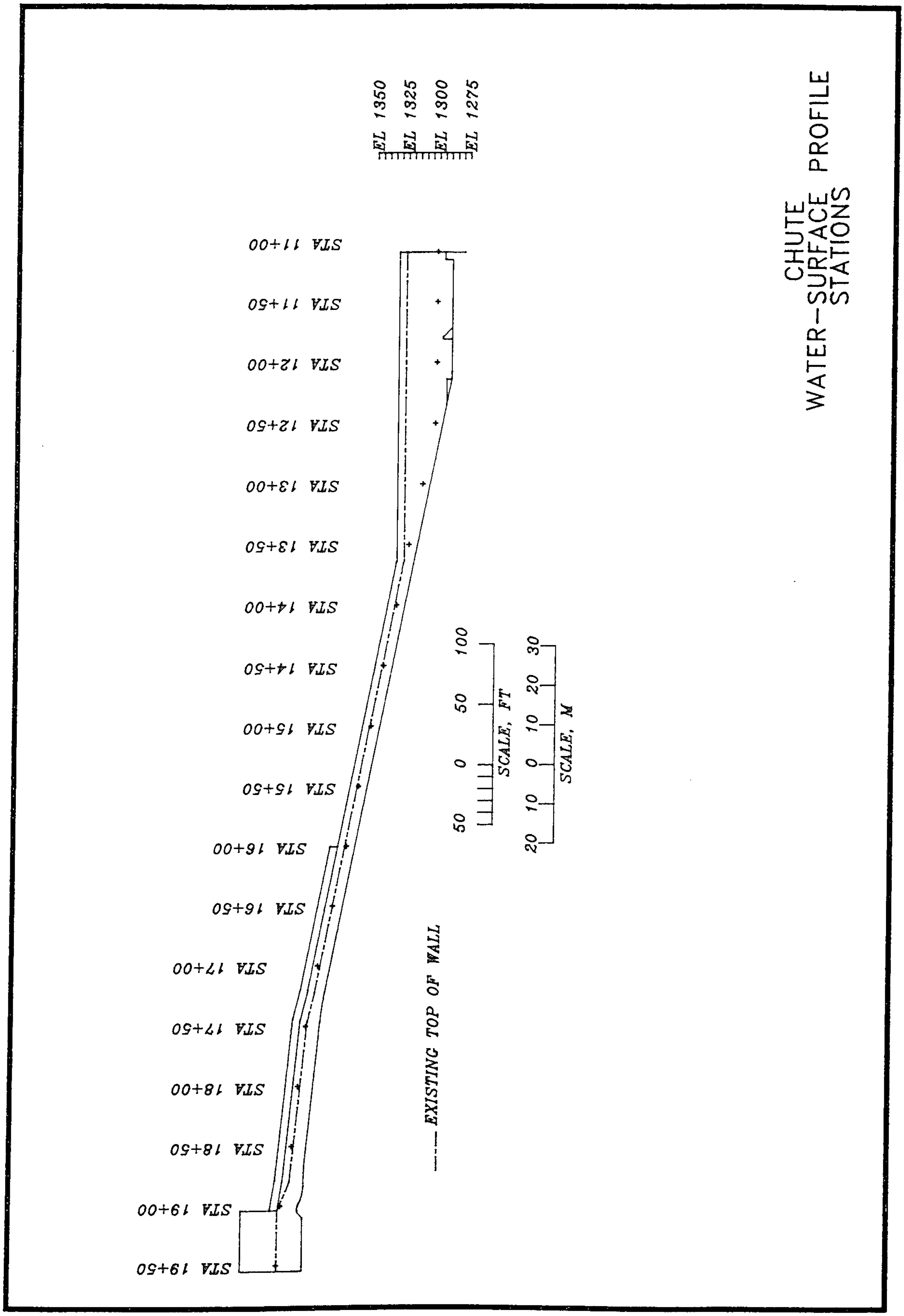
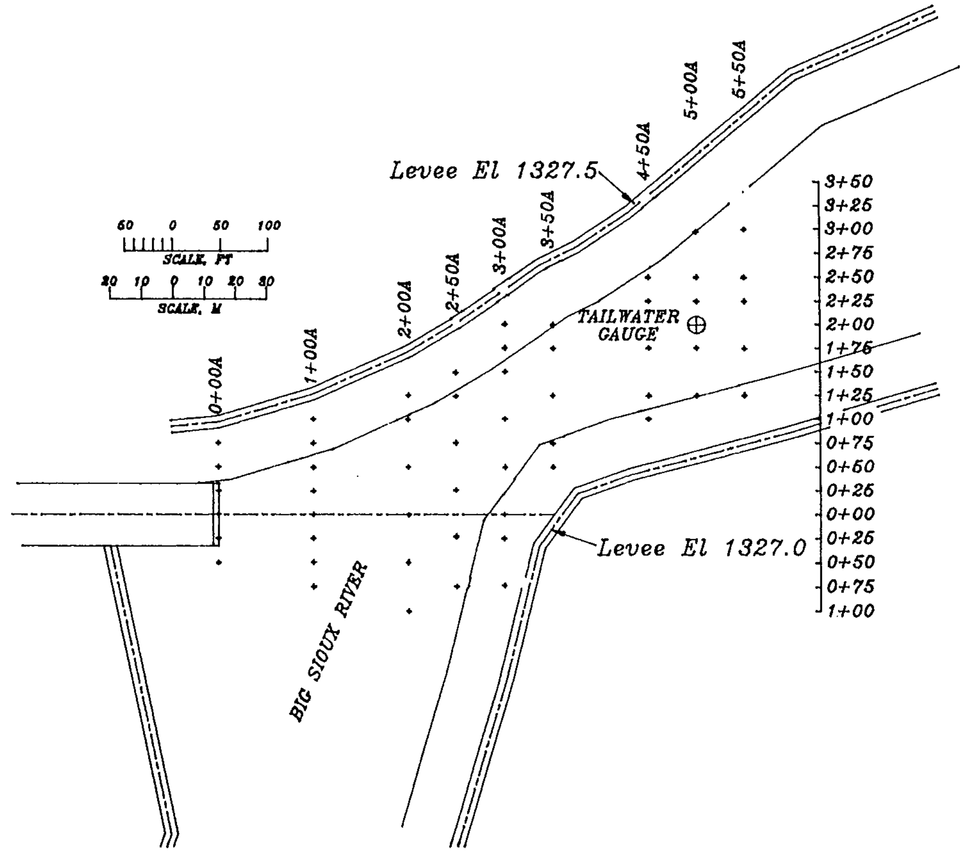
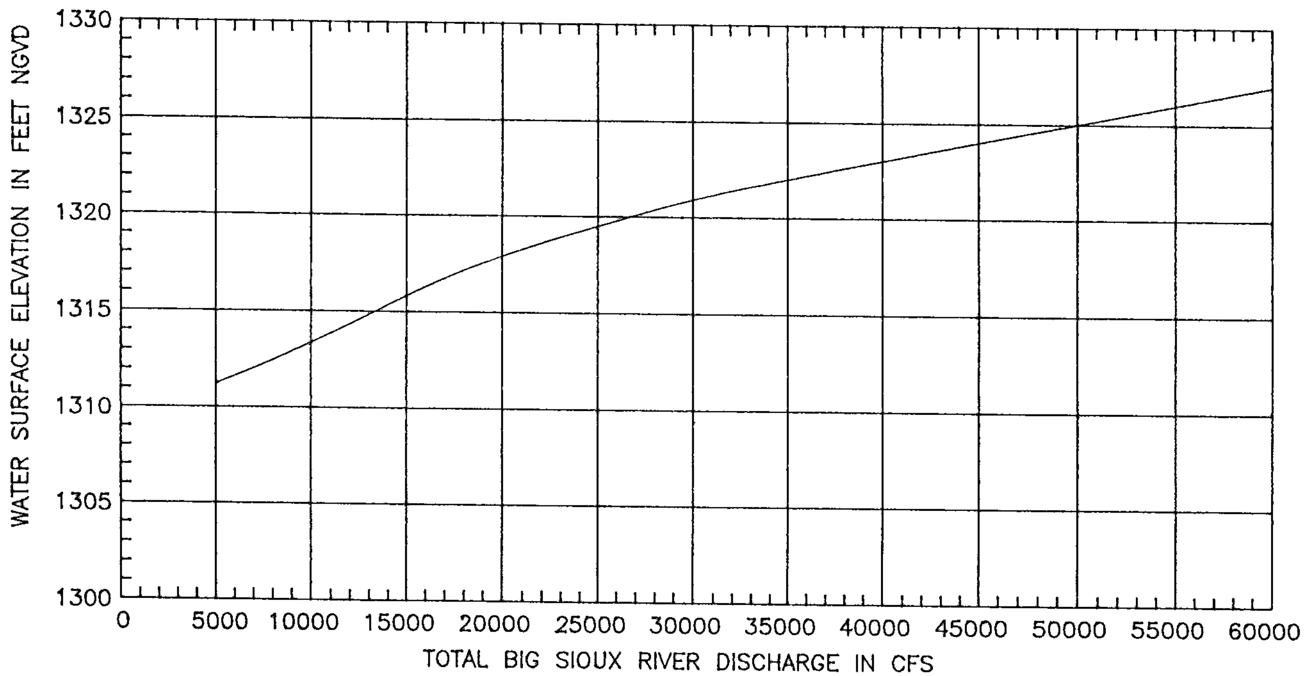

CHUTE
WATER-SURFACE PROFILE
STATIONS
EL 1350
EL 1325
EL 1300
EL 1275
STA 11+00
STA 11+50
STA 12+00
STA 12+50
STA 13+00
STA 13+50
STA 14+00
STA 14+50
STA 15+00
STA 15+50
STA 16+00
STA 16+50
STA 17+00
STA 17+50
STA 18+00
STA 18+50
STA 19+00
STA 19+50
50 0 50 100
SCALE, FT
20 10 0 10 20 30
SCALE, M
EXISTING TOP OF WALL

Plate 2

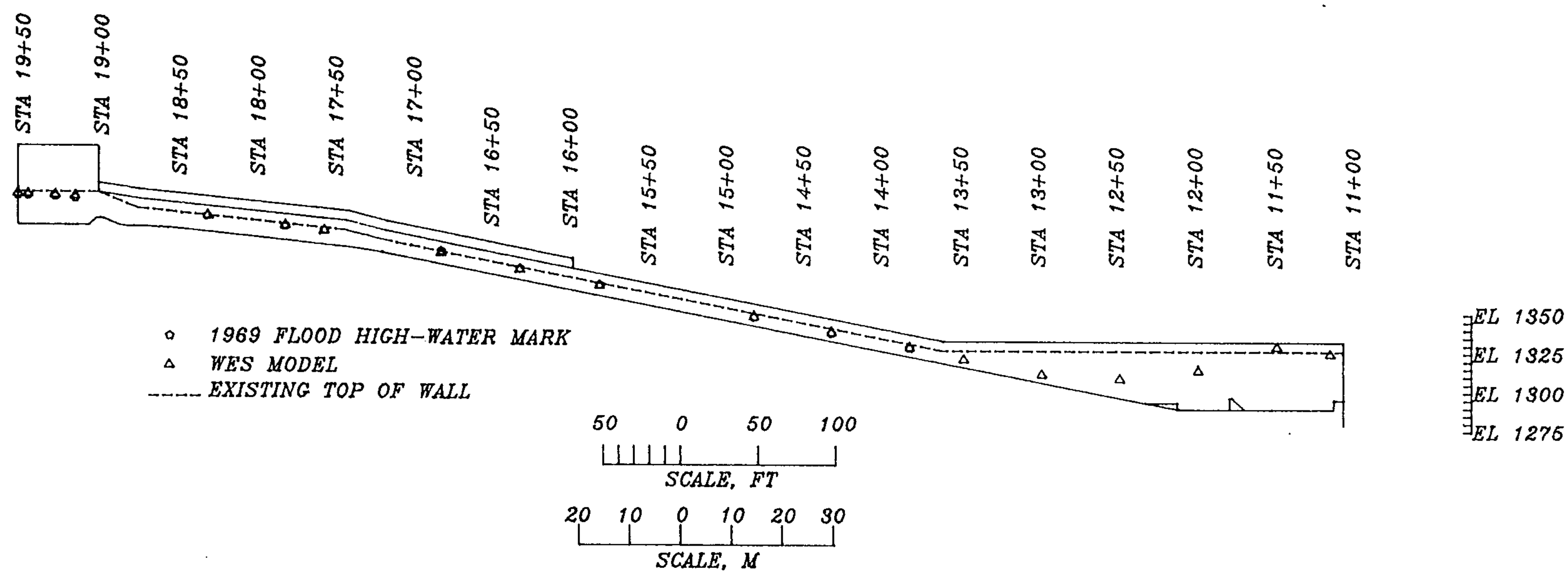


WATER–SURFACE ELEVATION AND VELOCITY
CHANNEL STATIONS
EXISTING CONDITIONS



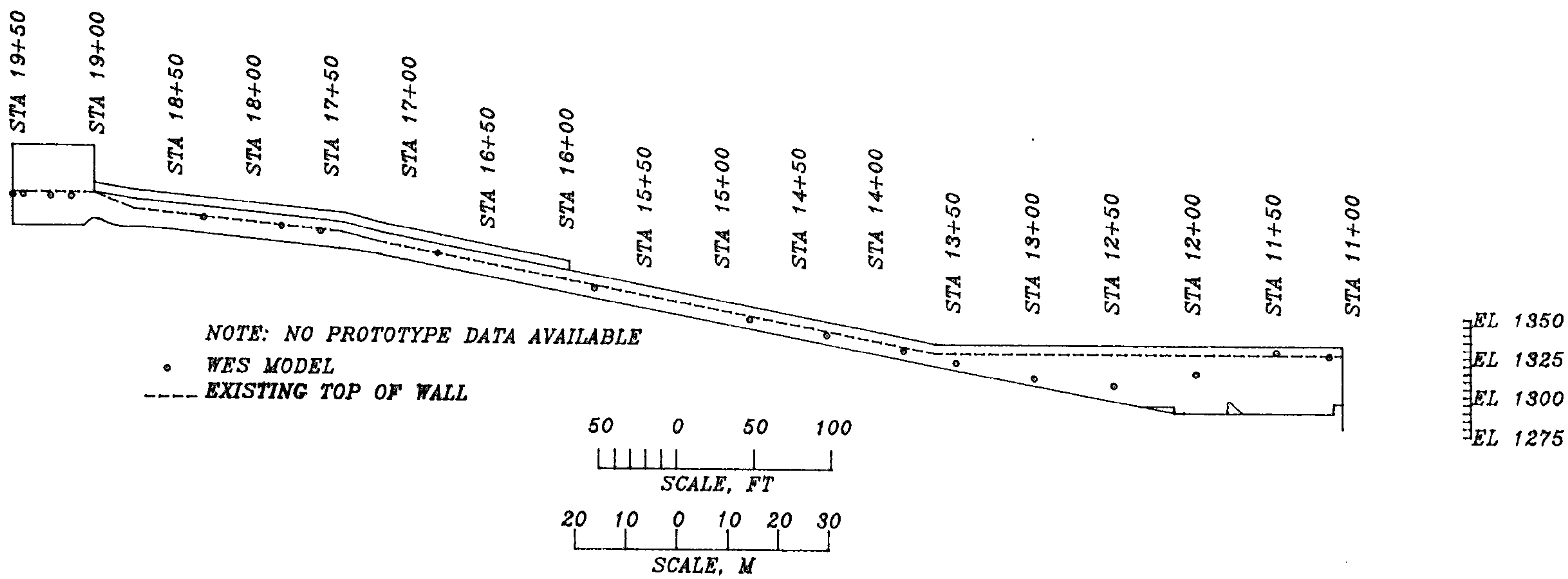
Note: To convert discharges to cu m/sec, multiply by 0.028.

DIVERSION SPILLWAY CHUTE
TAILWATER RATING CURVE



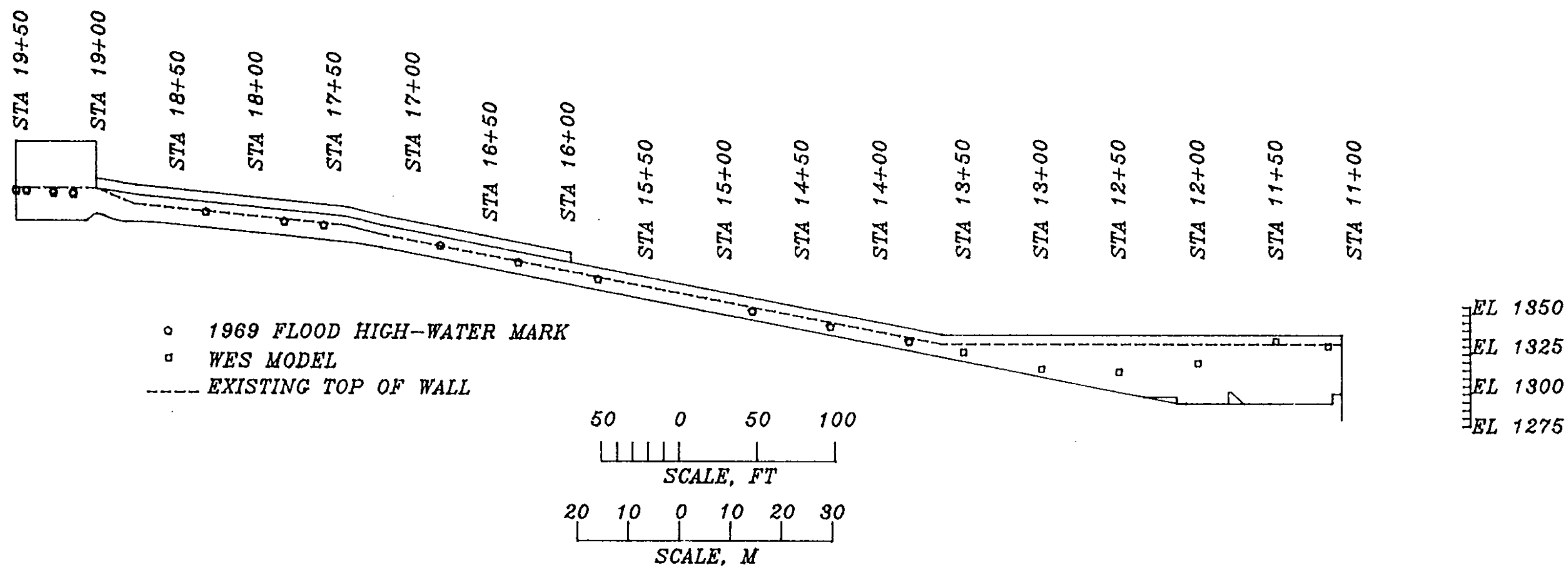
Note: See Table 1 for data

1969 FLOOD HIGH-WATER MARKS/WES MODEL
LEFT WALL
WATER-SURFACE PROFILES
EXISTING CONDITIONS
Q_C = 658 CU M/SEC (23,500 CFS)
Q_R = 280 CU M/SEC (10,000 CFS)
TAILWATER ELEVATION 1322.4



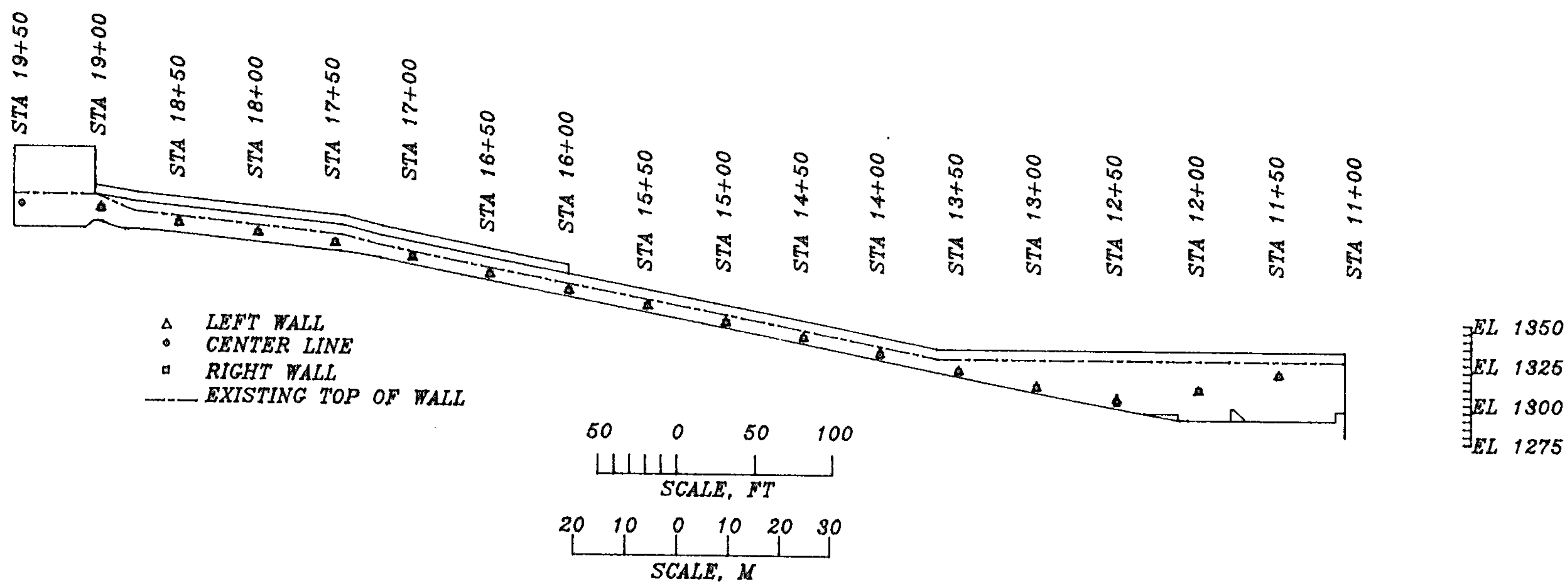
Note: See Table 1 for data

1969 FLOOD HIGH-WATER MARKS/WES MODEL
CENTER LINE
WATER-SURFACE PROFILES
EXISTING CONDITIONS
Q_C = 658 CU M/SEC (23,500 CFS)
Q_R = 280 CU M/SEC (10,000 CFS)
TAILWATER ELEVATION 1322.4



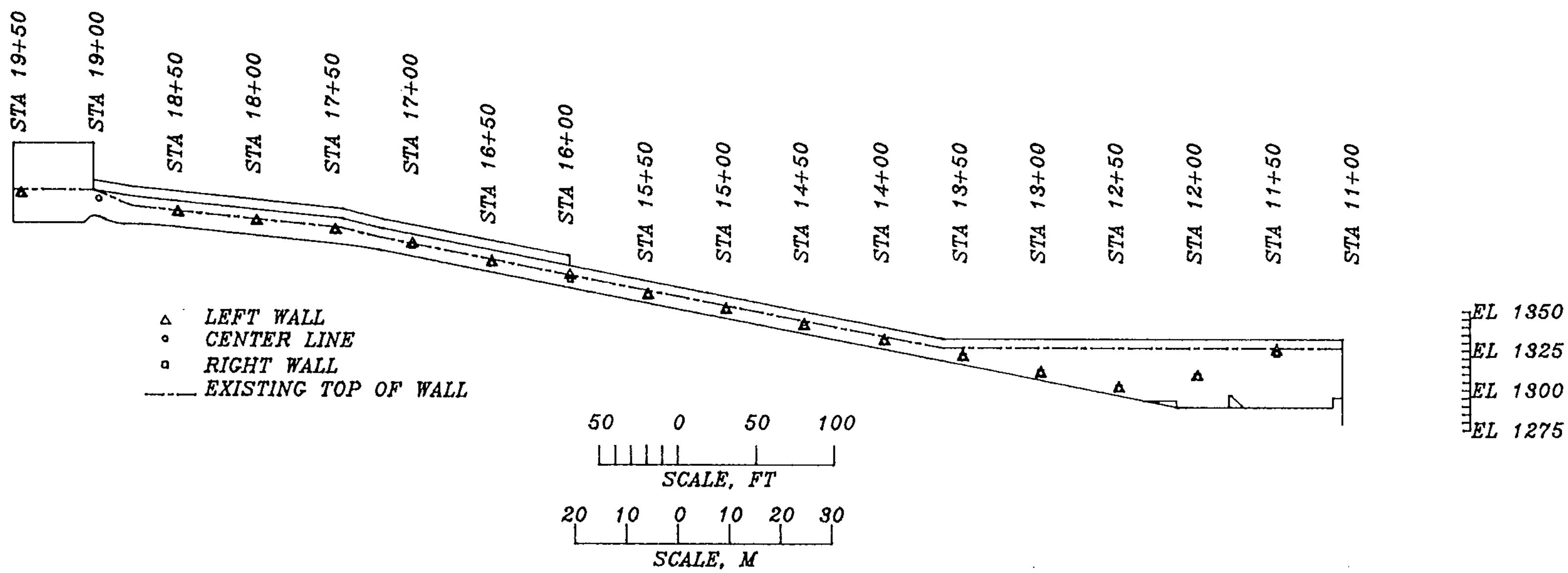
Note: See Table 1 for data

1969 FLOOD HIGH-WATER MARKS/WES MODEL
RIGHT WALL
WATER-SURFACE PROFILES
EXISTING CONDITIONS
Q_C = 658 CU M/SEC (23,500 CFS)
Q_R = 280 CU M/SEC (10,000 CFS)
TAILWATER ELEVATION 1322.4



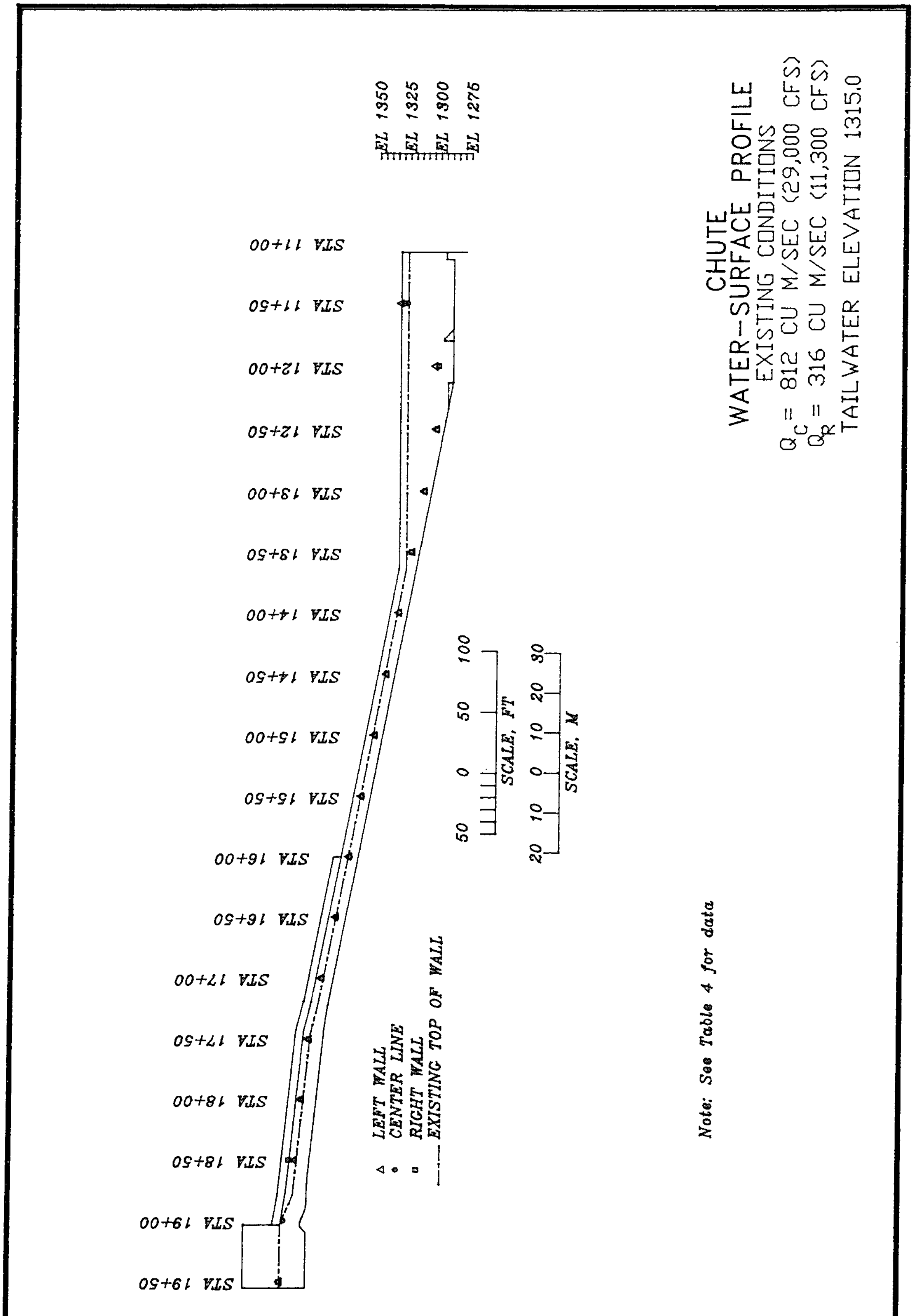
Note: See Table 2 for data

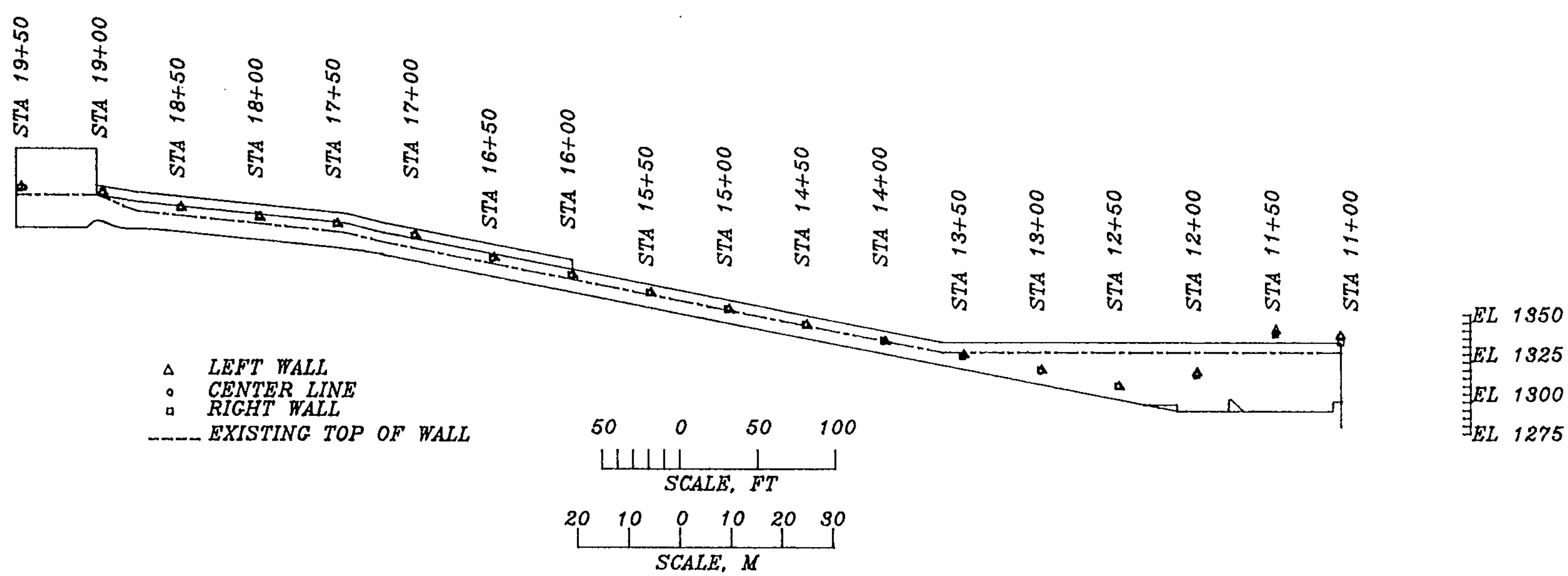
CHUTE
WATER–SURFACE PROFILE
EXISTING CONDITIONS
Q_C = 356 CU M/SEC (12,700 CFS)
Q_C = 6 CU M/SEC (200 CFS)
TAILWATER ELEVATION 1315.0



Note: See Table 3 for data

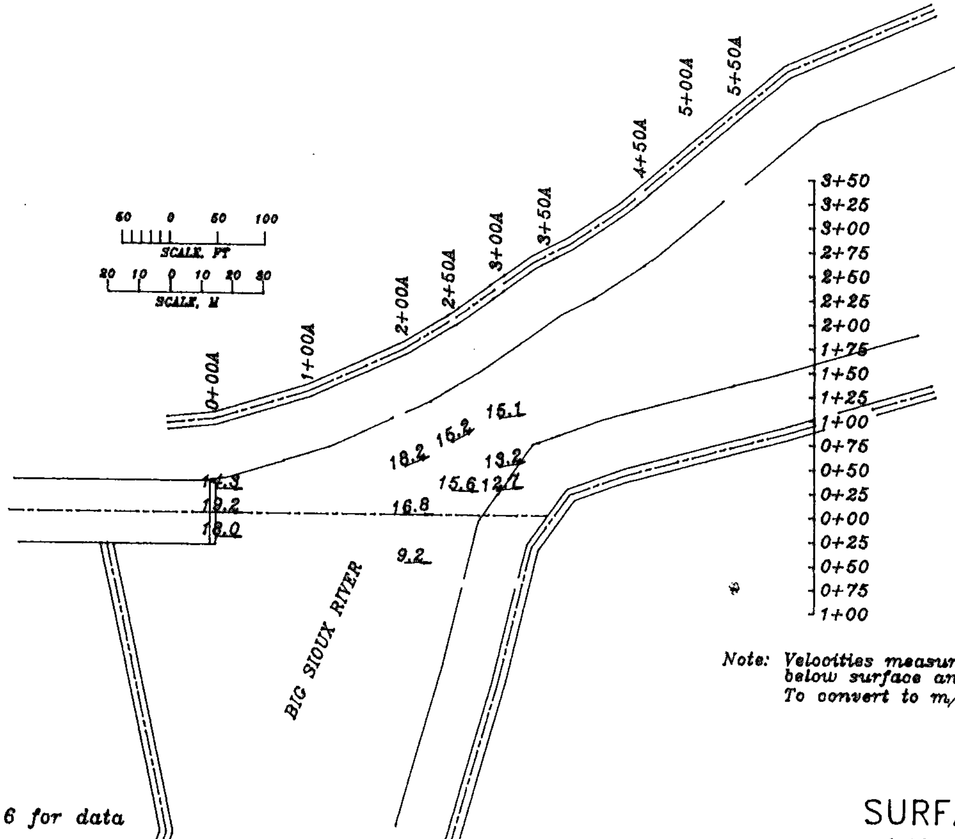
CHUTE
WATER–SURFACE PROFILE
EXISTING CONDITIONS
Q_C = 591 CU M/SEC (21,100 CFS)
Q_R = 174 CU M/SEC (6,200 CFS)
TAILWATER ELEVATION 1320.2


CHUTE
WATER-SURFACE PROFILE
EXISTING CONDITIONS
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 316 CU M/SEC (11,300 CFS)
TAILWATER ELEVATION 1315.0
EL 1350
EL 1325
EL 1300
EL 1275
STA 11+00
STA 11+50
STA 12+00
STA 12+50
STA 13+00
STA 13+50
STA 14+00
STA 14+50
STA 15+00
STA 15+50
STA 16+00
STA 16+50
STA 17+00
STA 17+50
STA 18+00
STA 18+50
STA 19+00
STA 19+50
50 0 50 100
SCALE, FT
20 10 0 10 20 30
SCALE, M
LEFT WALL
CENTER LINE
RIGHT WALL
EXISTING TOP OF WALL
Note: See Table 4 for data



Note: See Table 5 for data

CHUTE
WATER-SURFACE PROFILES
EXISTING CONDITIONS
Q_C = 1,044 CU M/SEC (37,300 CFS)
Q_R = 812 CU M/SEC (29,000 CFS)
TAILWATER ELEVATION 1327.0



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 6 for data

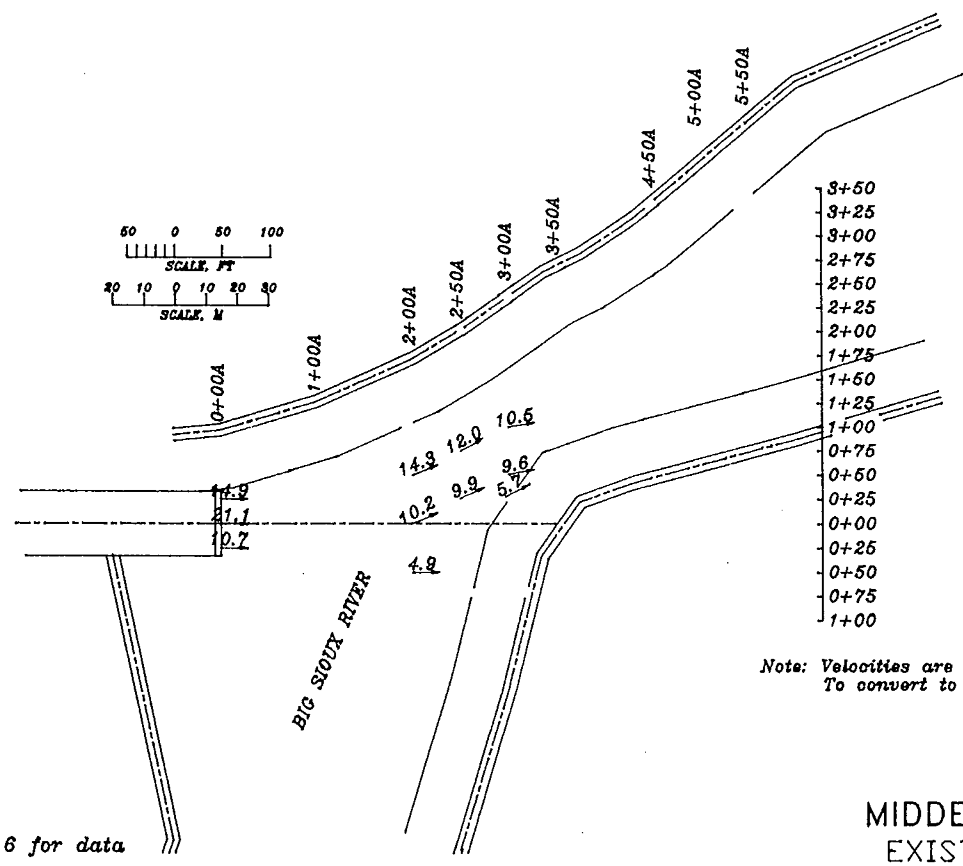
SURFACE VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 168 CU M/SEC (6,000 CFS)

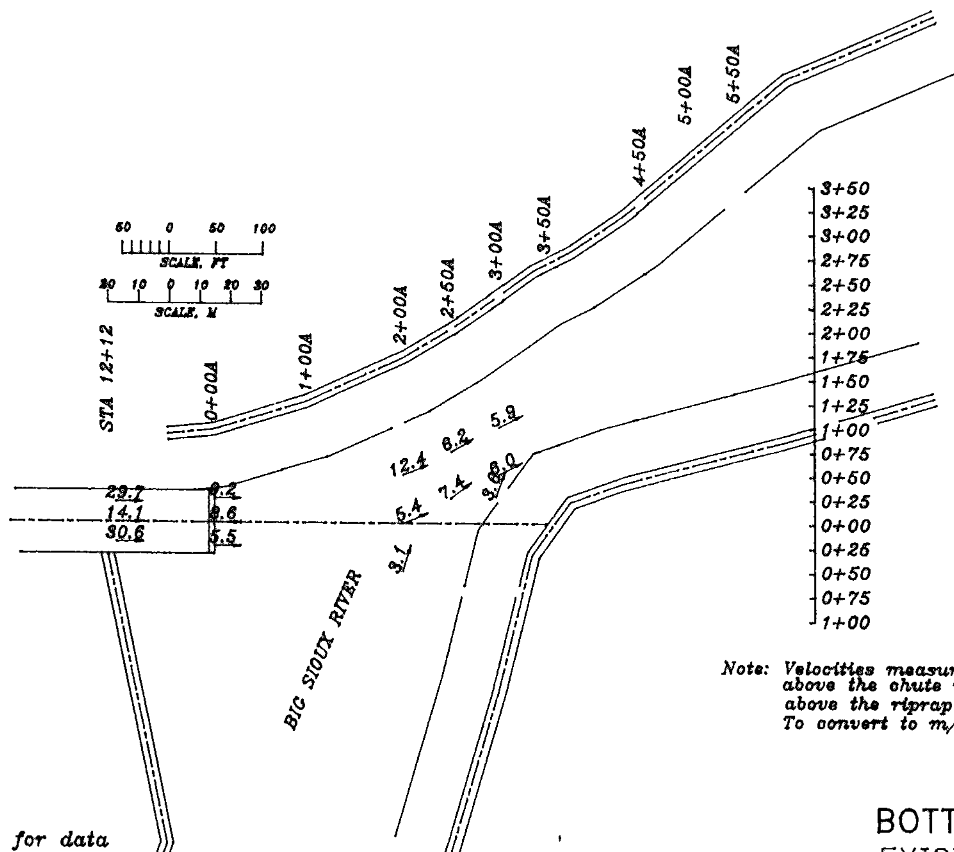
TAILWATER ELEVATION 1322.0



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 6 for data

MIDDEPTH VELOCITIES
EXISTING CONDITIONS
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 168 CU M/SEC (6,000 CFS)
TAILWATER ELEVATION 1322.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 6 for data

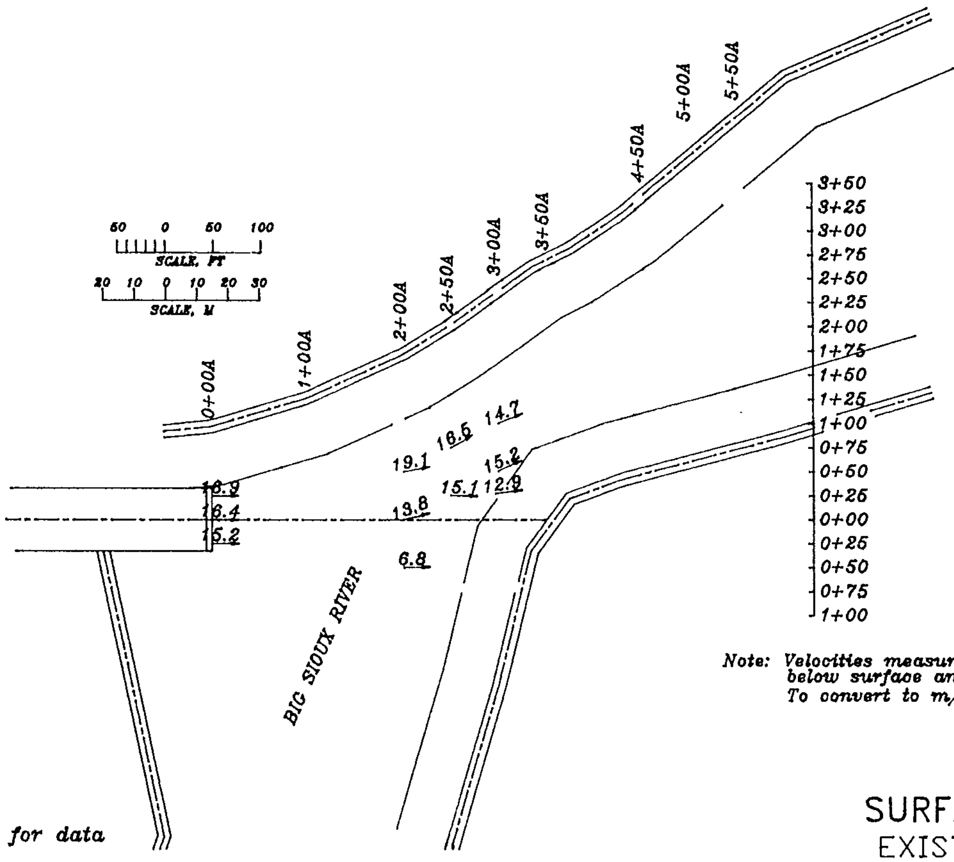
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 168 CU M/SEC (6,000 CFS)

TAILWATER ELEVATION 1322.0



Note: See Table 7 for data

Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

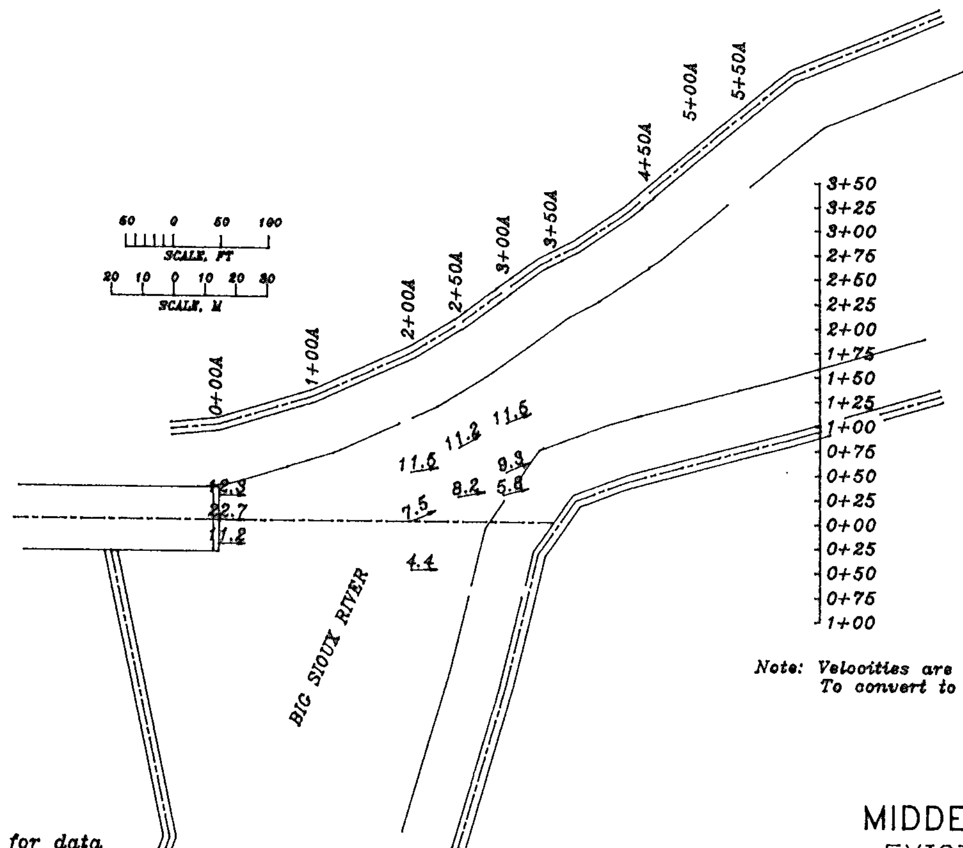
SURFACE VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 224 CU M/SEC (8,000 CFS)

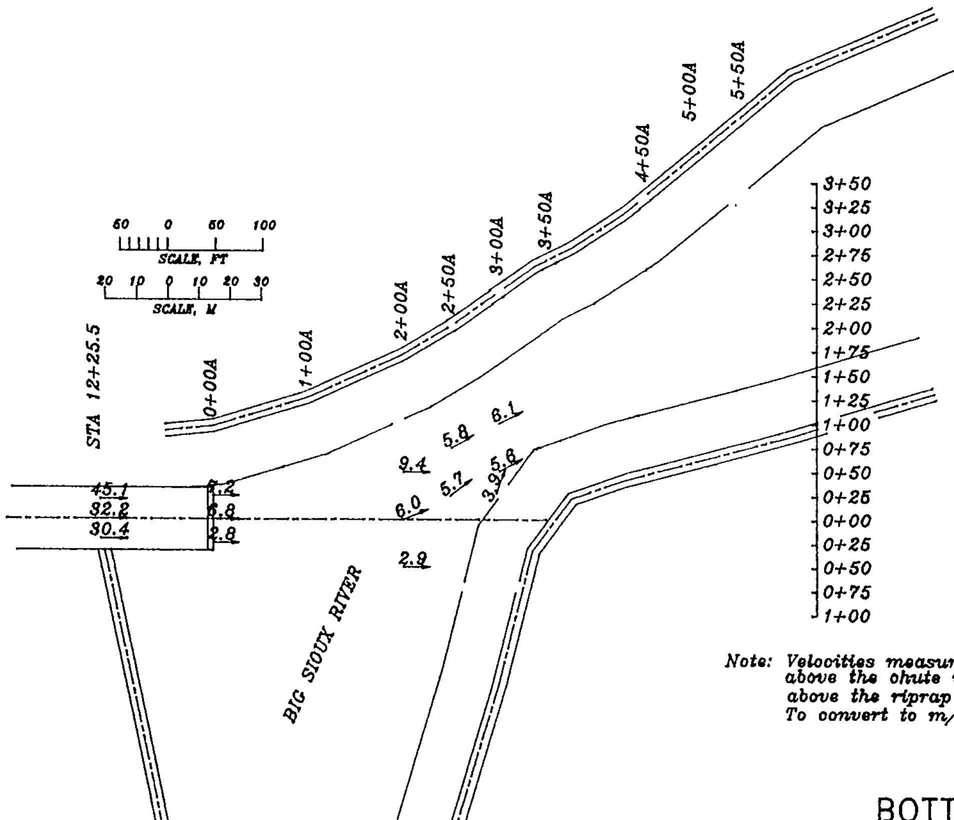
TAILWATER ELEVATION 1322.5



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 7 for data

MIDDEPTH VELOCITIES
EXISTING CONDITIONS
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 224 CU M/SEC (8,000 CFS)
TAILWATER ELEVATION 1322.5



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 7 for data

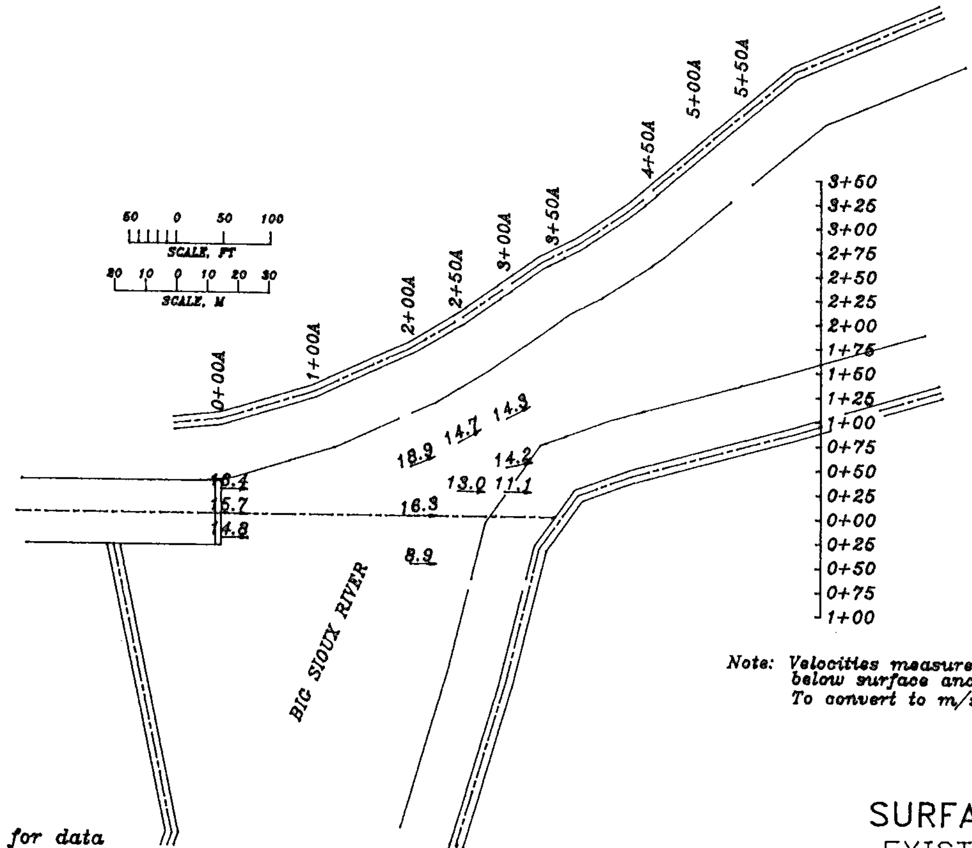
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 224 CU M/SEC (8,000 CFS)

TAILWATER ELEVATION 1322.5



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 8 for data

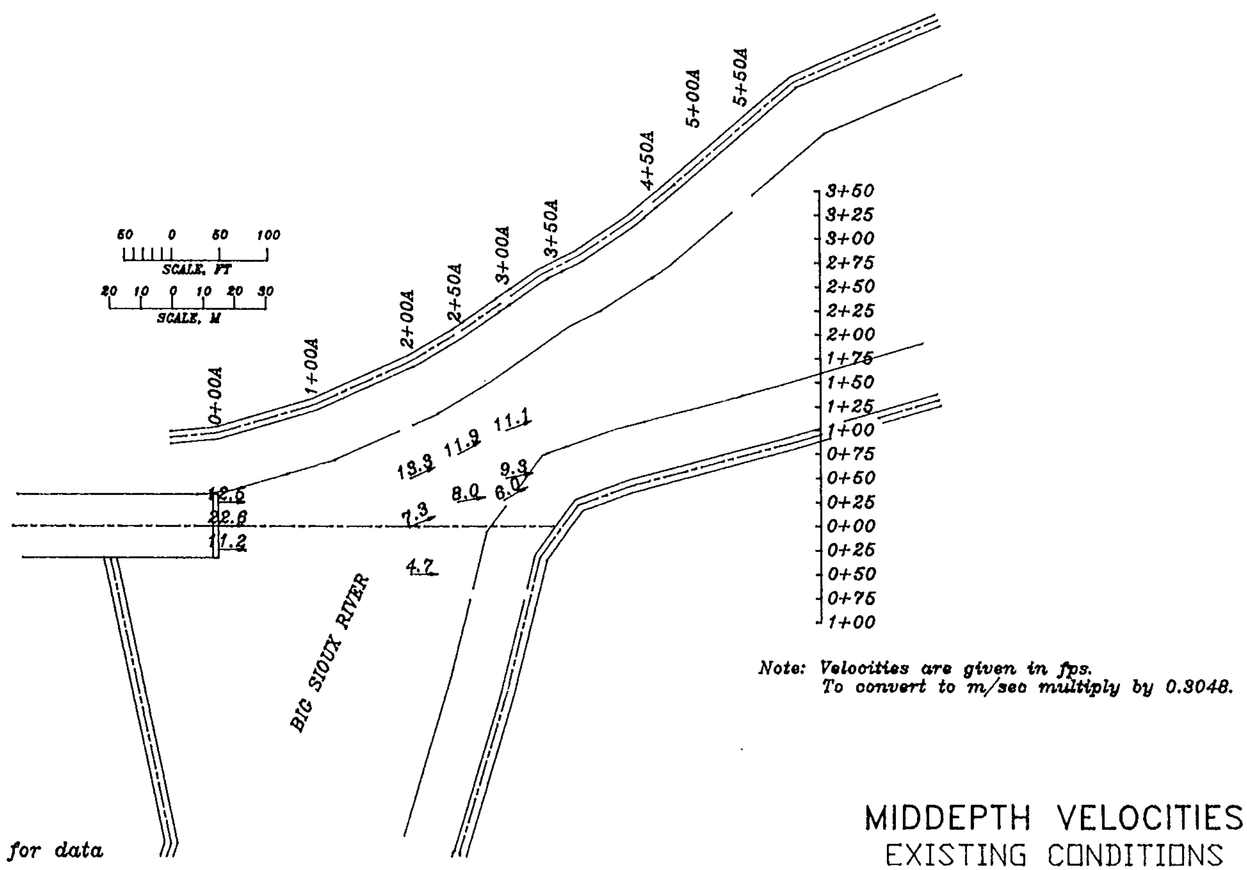
SURFACE VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 280 CU M/SEC (10,000 CFS)

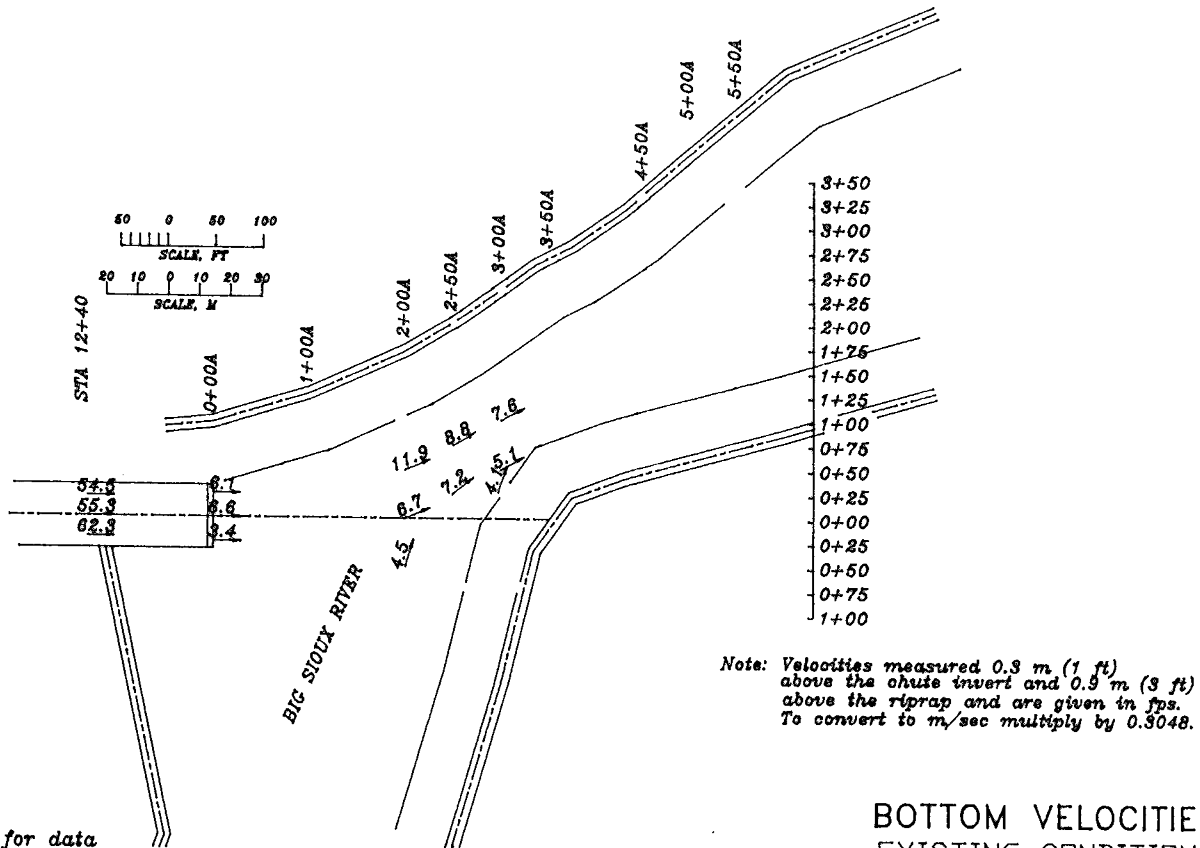
TAILWATER ELEVATION 1322.8



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 8 for data

MIDDEPTH VELOCITIES
EXISTING CONDITIONS
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 280 CU M/SEC (10,000 CFS)
TAILWATER ELEVATION 1322.8



Note: See Table 8 for data

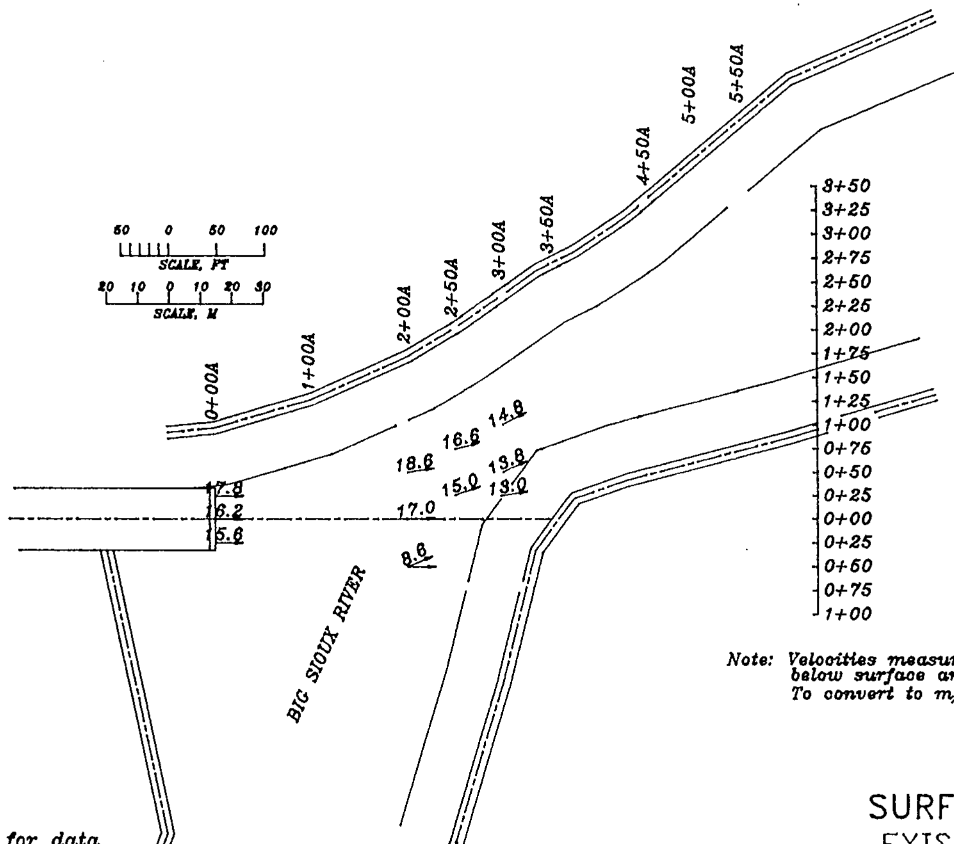
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 280 CU M/SEC (10,000 CFS)

TAILWATER ELEVATION 1322.8



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 9 for data

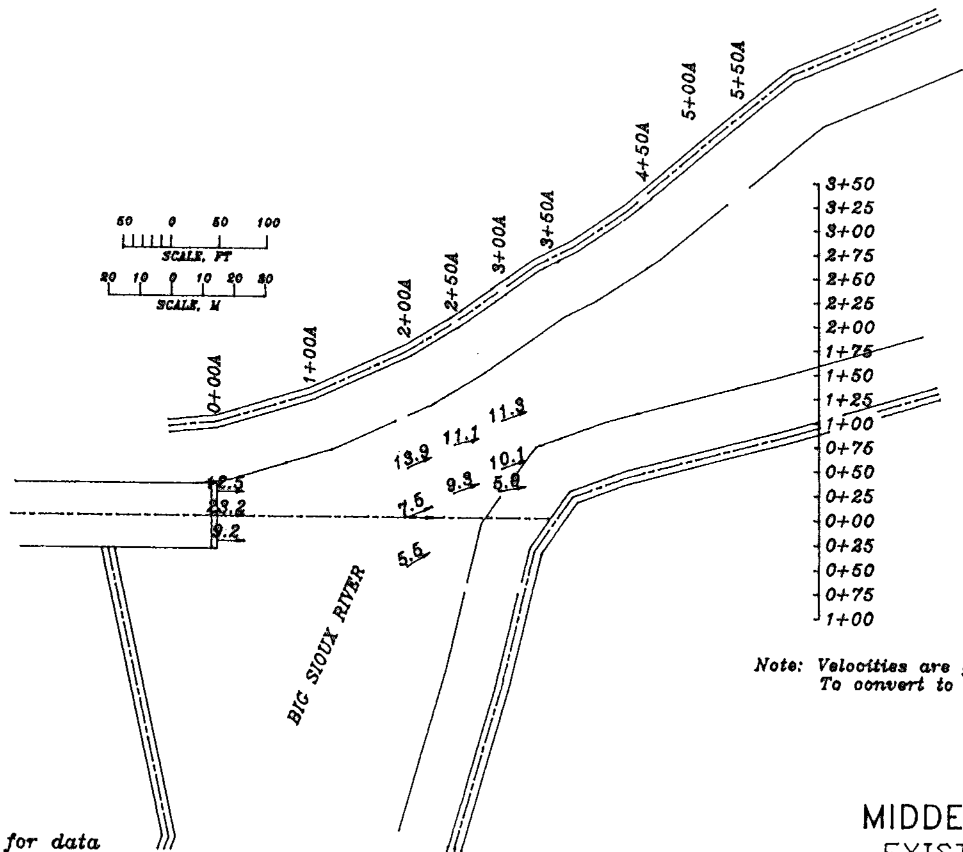
SURFACE VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 336 CU M/SEC (12,000 CFS)

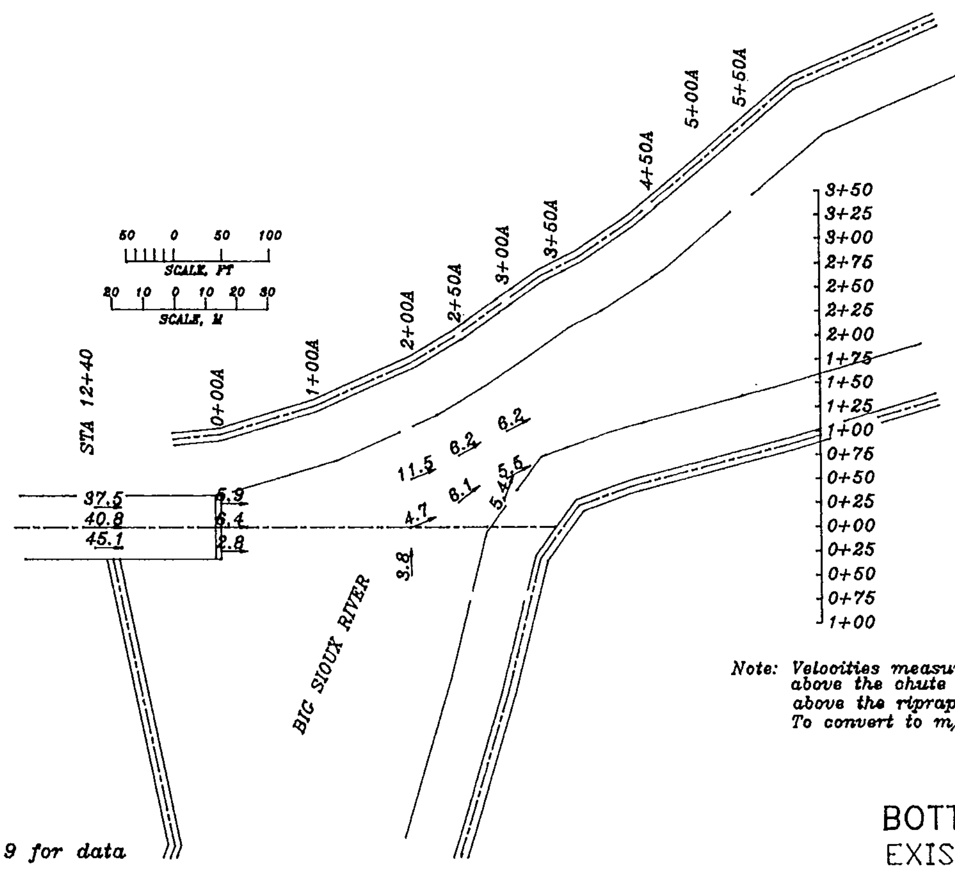
TAILWATER ELEVATION 1323.1



Note: See Table 9 for data

Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

MIDDEPTH VELOCITIES
EXISTING CONDITIONS
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 336 CU M/SEC (12,000 CFS)
TAILWATER ELEVATION 1323.1



Note: See Table 9 for data

Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

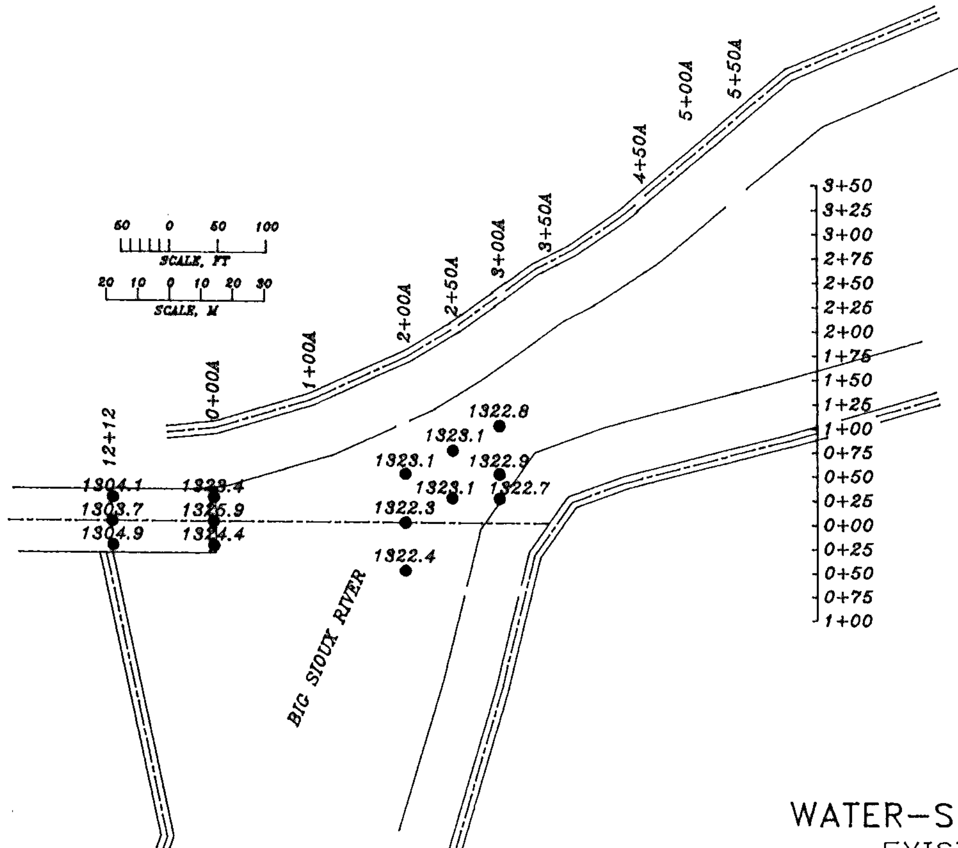
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 336 CU M/SEC (12,000 CFS)

TAILWATER ELEVATION 1323.1



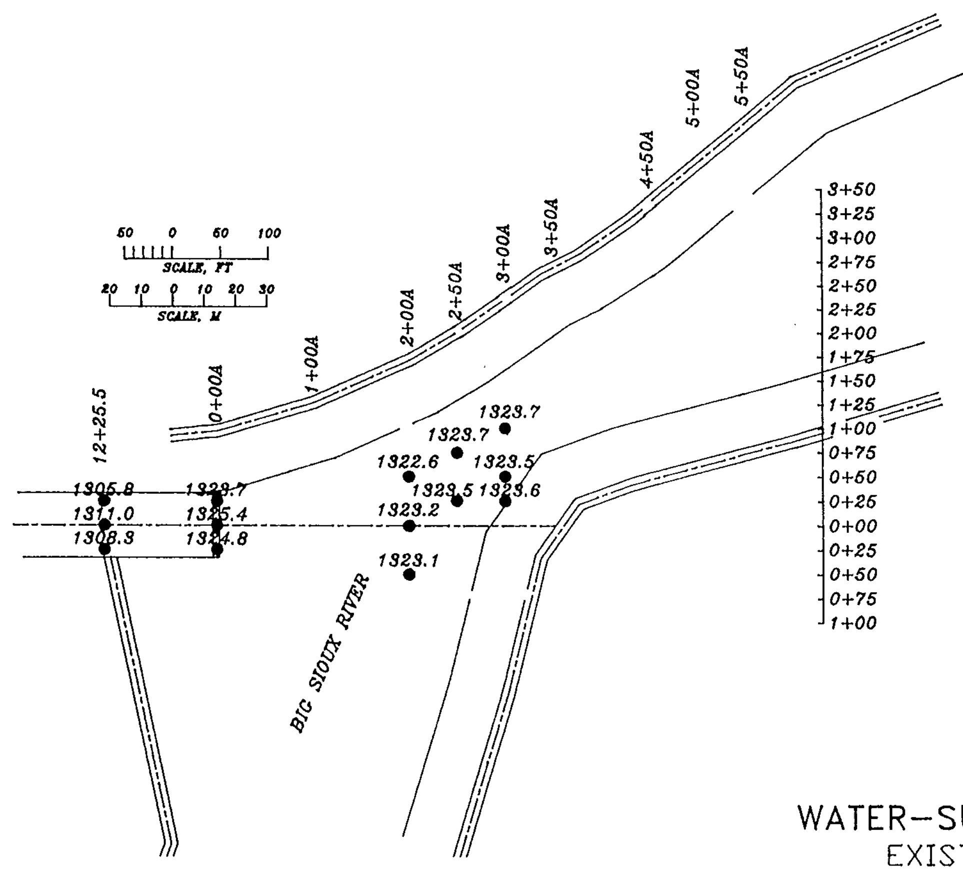
WATER–SURFACE ELEVATIONS

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 168 CU M/SEC (6,000 CFS)

TAILWATER ELEVATION 1322.0



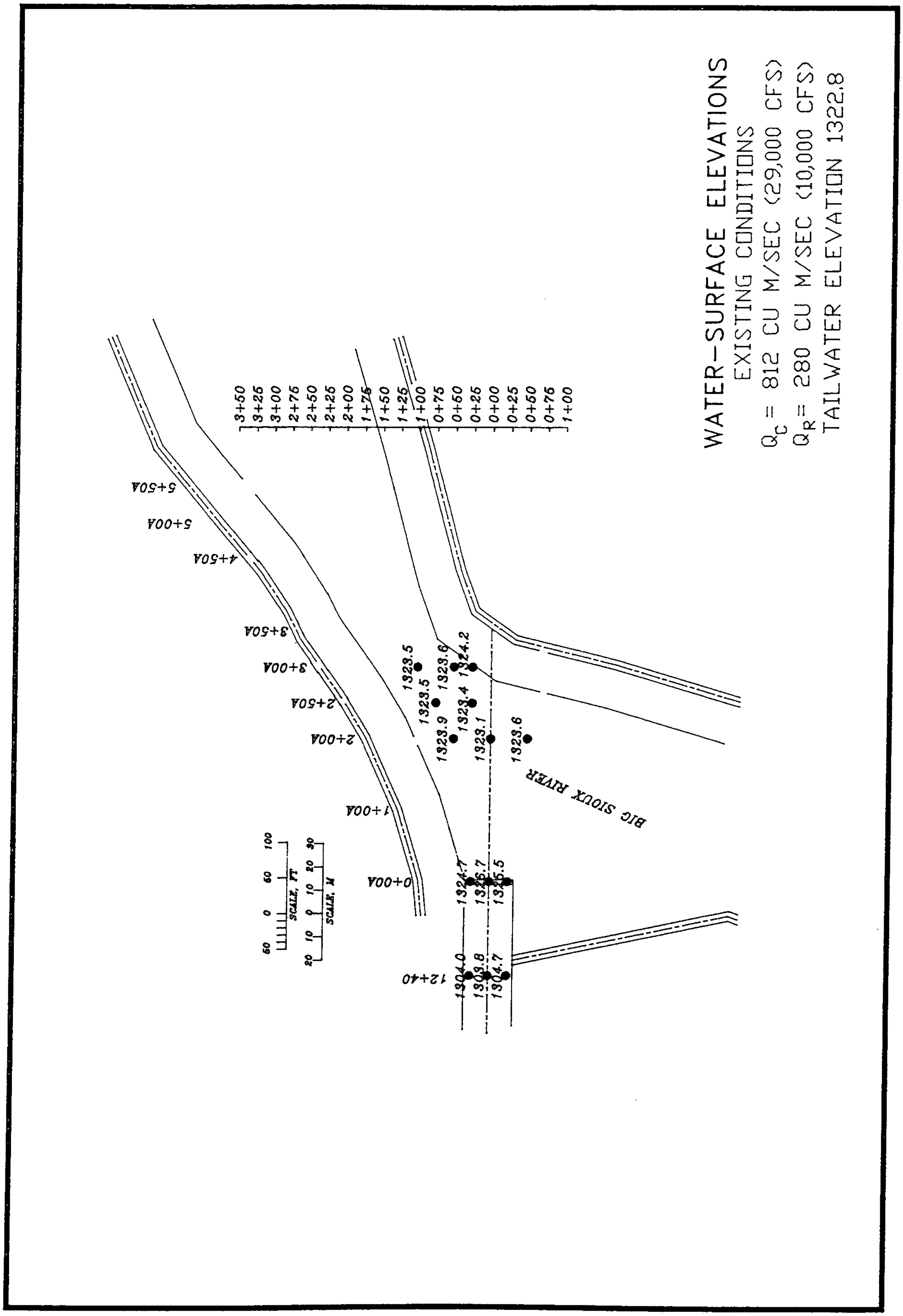
WATER—SURFACE ELEVATIONS

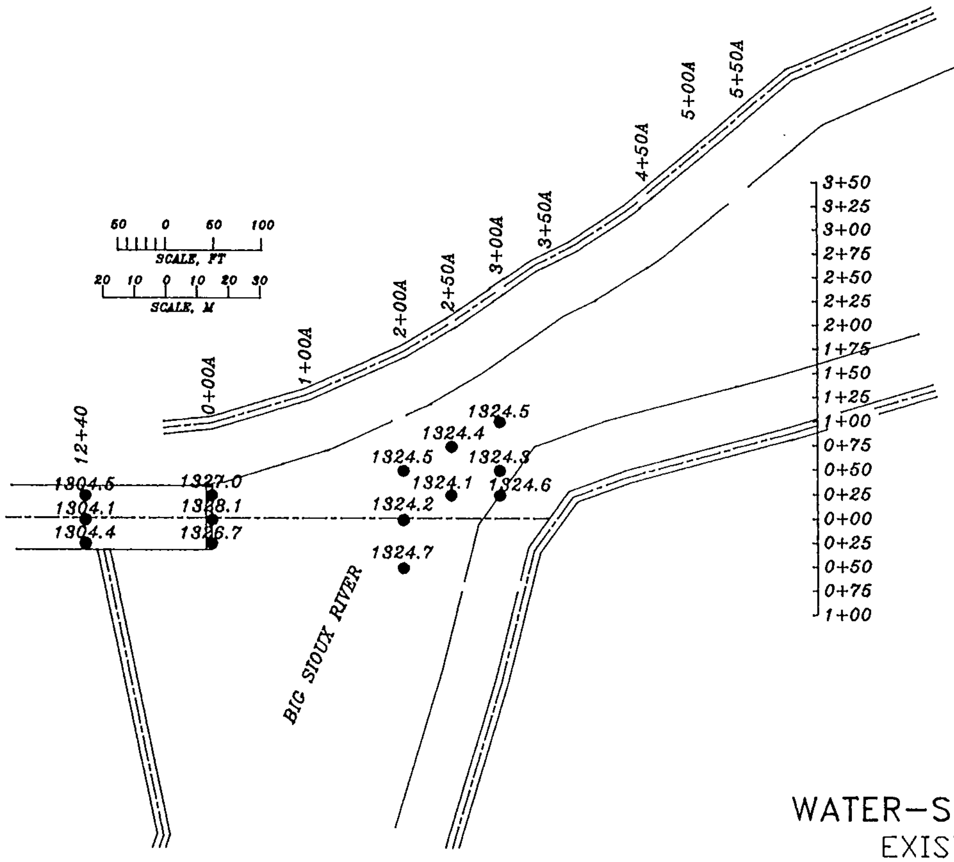
EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 224 CU M/SEC (8,000 CFS)

TAILWATER ELEVATION 1322.5


WATER-SURFACE ELEVATIONS
EXISTING CONDITIONS
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 280 CU M/SEC (10,000 CFS)
TAILWATER ELEVATION 1322.8
BIG SIOUX RIVER
3+50
3+25
3+00
2+75
2+50
2+25
2+00
1+75
1+50
1+25
1+00
0+75
0+50
0+25
0+00
0+25
0+50
0+75
1+00
5+50A
5+00A
4+50A
3+50A
3+00A
2+50A
2+00A
1+00A
0+00A
12+40
1323.5
1323.6
1324.2
1323.5
1323.4
1323.9
1323.1
1323.6
1324.7
1304.0
1304.7
SCALE, FT
SCALE, M



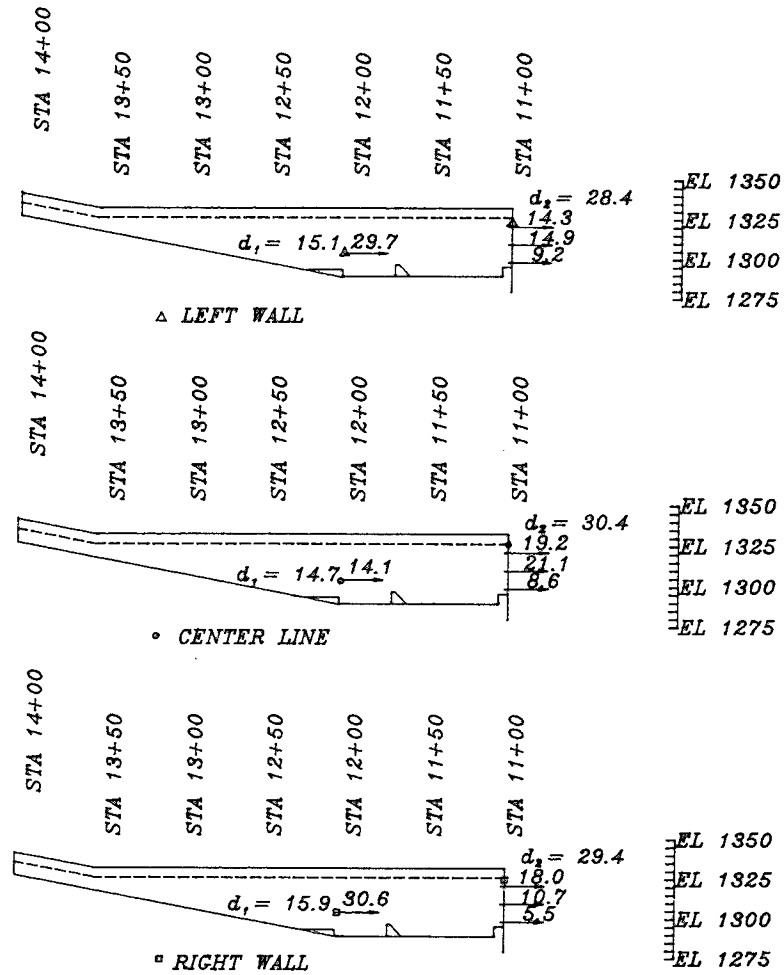
WATER–SURFACE ELEVATIONS

EXISTING CONDITIONS

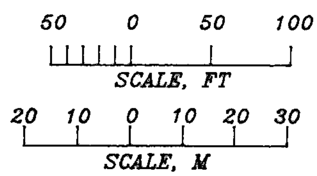
Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 336 CU M/SEC (12,000 CFS)

TAILWATER ELEVATION 1323.1

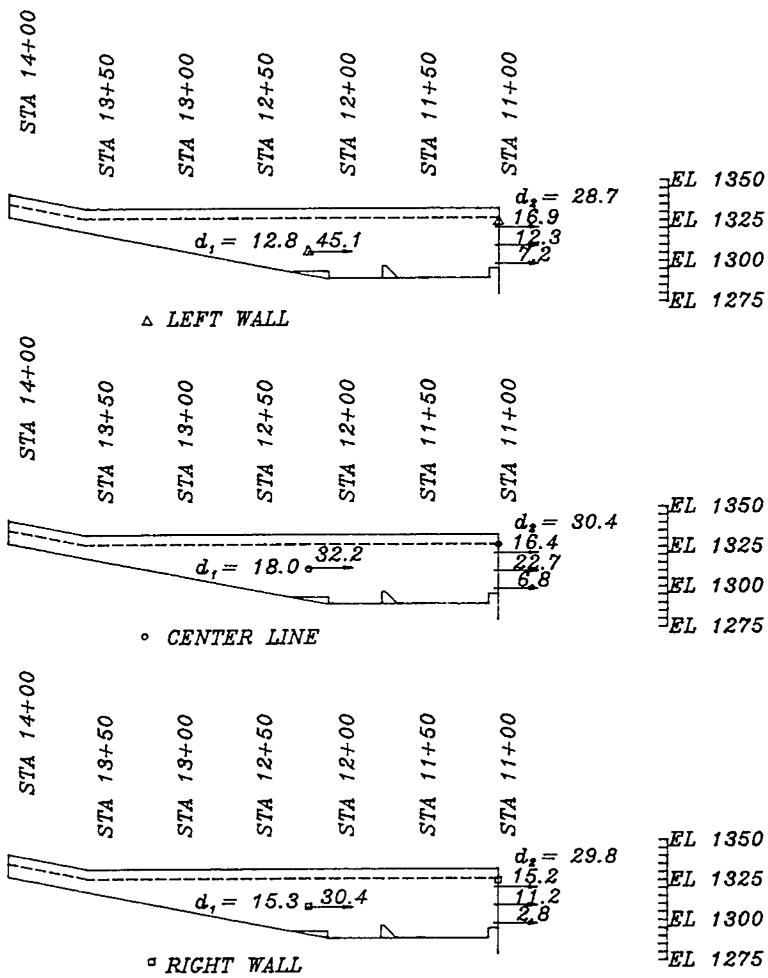


Note: See Table 10 for data

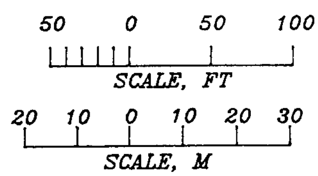


Note: Dimensions given in feet.
To convert to m, multiply by 0.3048.
Velocities measured 0.3 m (1 ft)
below surface and above end sill
and are given in fps. To convert
To convert to m/sec multiply by 0.3048.

D_1, V_1, D_2, V_2
EXISTING CHANNEL CONFIGURATION
TYPE 1 STILLING BASIN
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 168 CU M/SEC (6,000 CFS)
TAILWATER ELEVATION 1322.0

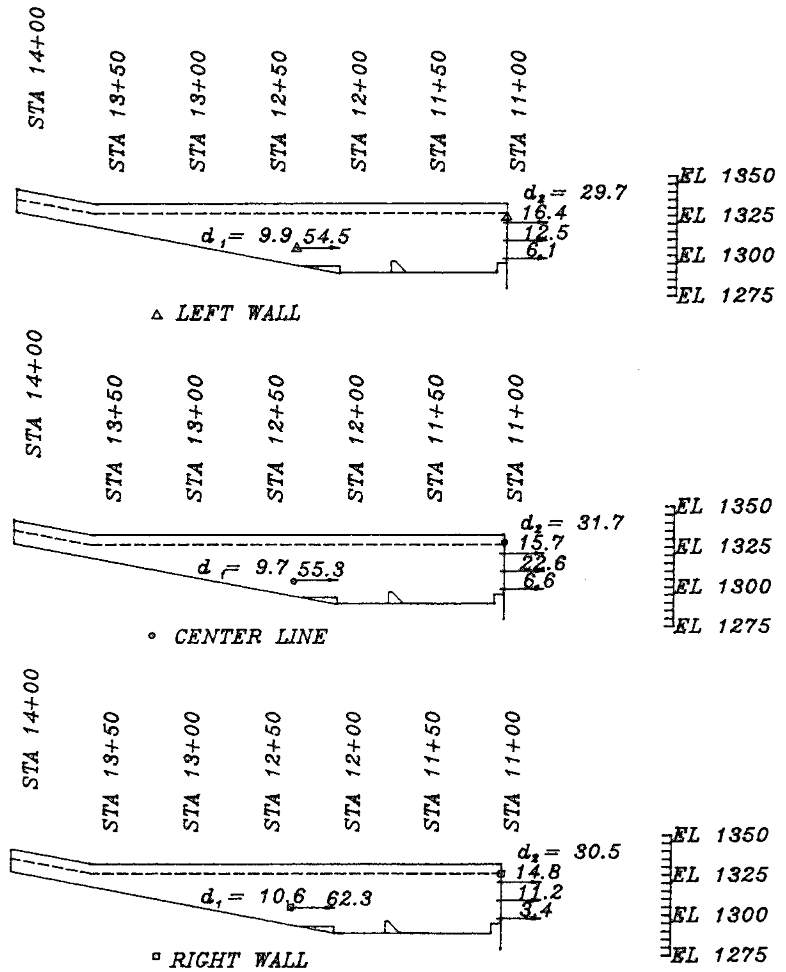


Note: See Table 10 for data

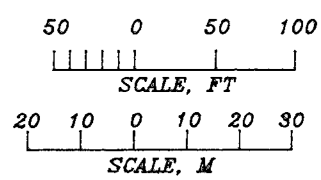


*Note: Dimensions given in feet.
To convert to m, multiply by 0.3048.
Velocities measured 0.3 m (1 ft)
below surface and above end sill
and are given in fps. To convert
To convert to m/sec multiply by 0.3048.*

D_1, V_1, D_2, V_2
EXISTING CHANNEL CONFIGURATION
TYPE 1 STILLING BASIN
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 224 CU M/SEC (8,000 CFS)
TAILWATER ELEVATION 1322.5

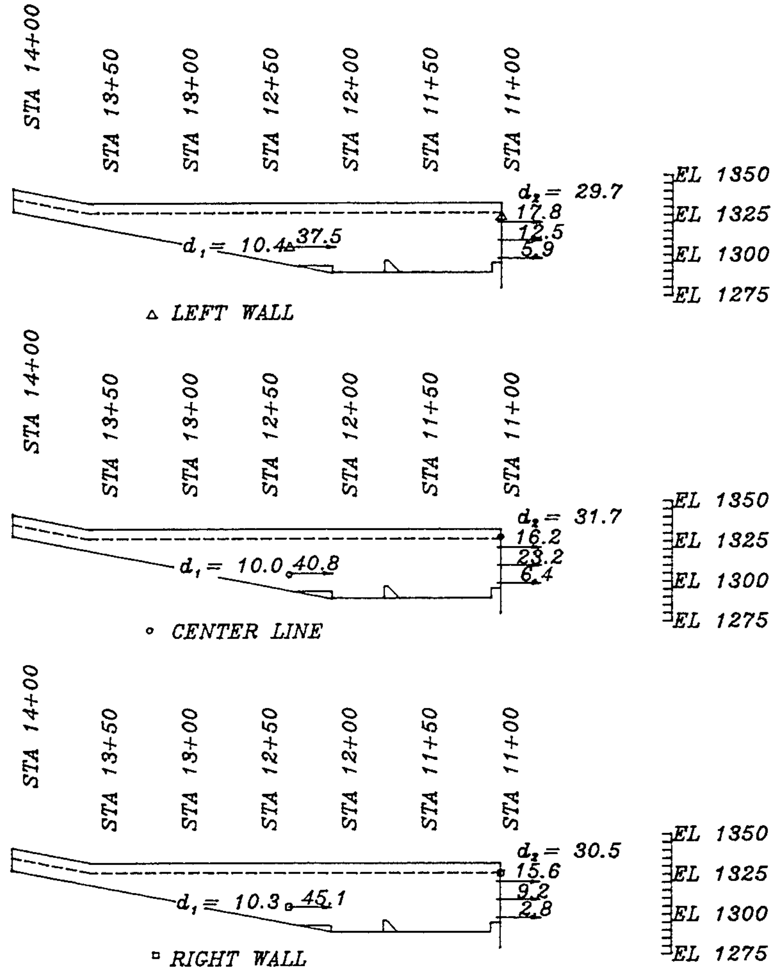


Note: See Table 10 for data

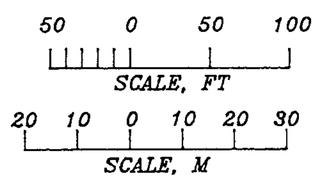


Note: Dimensions given in feet.
To convert to m, multiply by 0.3048.
Velocities measured 0.3 m (1 ft)
below surface and above end sill
and are given in fps. To convert
To convert to m/sec multiply by 0.3048.

D_1, V_1, D_2, V_2
EXISTING CHANNEL CONFIGURATION
TYPE 1 STILLING BASIN
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 280 CU M/SEC (10,000 CFS)
TAILWATER ELEVATION 1322.8



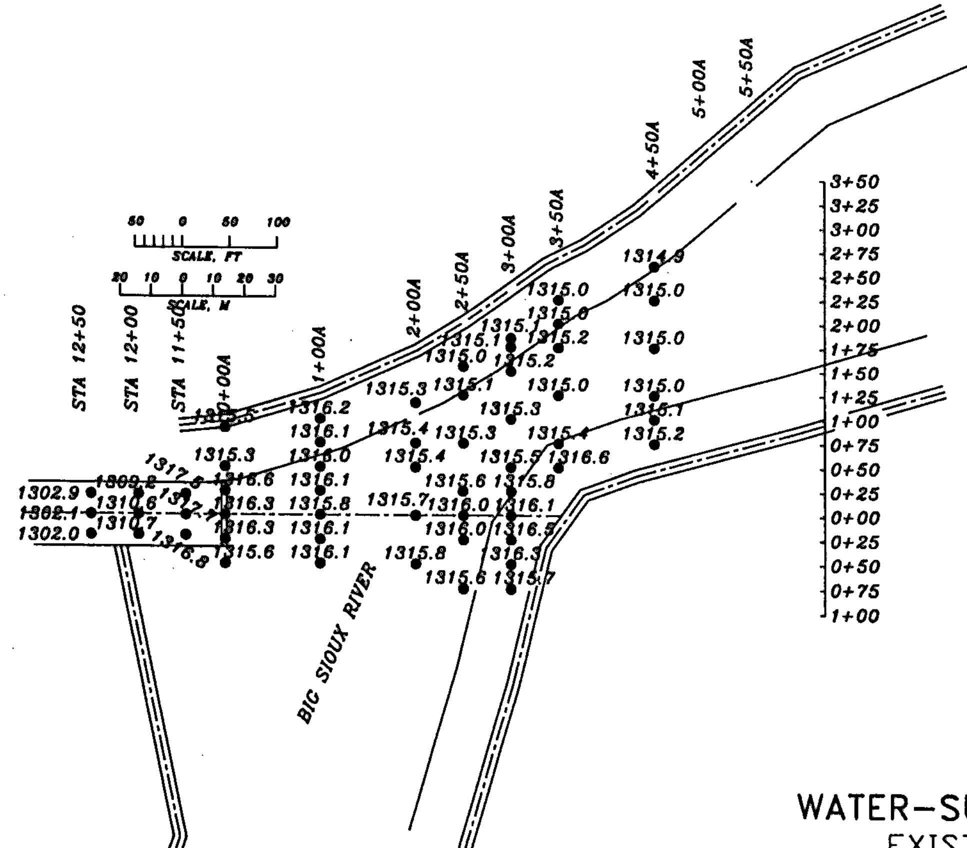
Note: See Table 10 for data



Note: Dimensions given in feet.
To convert to m, multiply by 0.3048.
Velocities measured 0.3 m (1 ft)
below surface and above end sill
and are given in fps. To convert
To convert to m/sec multiply by 0.3048.

D_1, V_1, D_2, V_2

EXISTING CHANNEL CONFIGURATION
TYPE 1 BASIN
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 336 CU M/SEC (12,000 CFS)
TAILWATER ELEVATION 1323.1



Note: See Table 13 for data

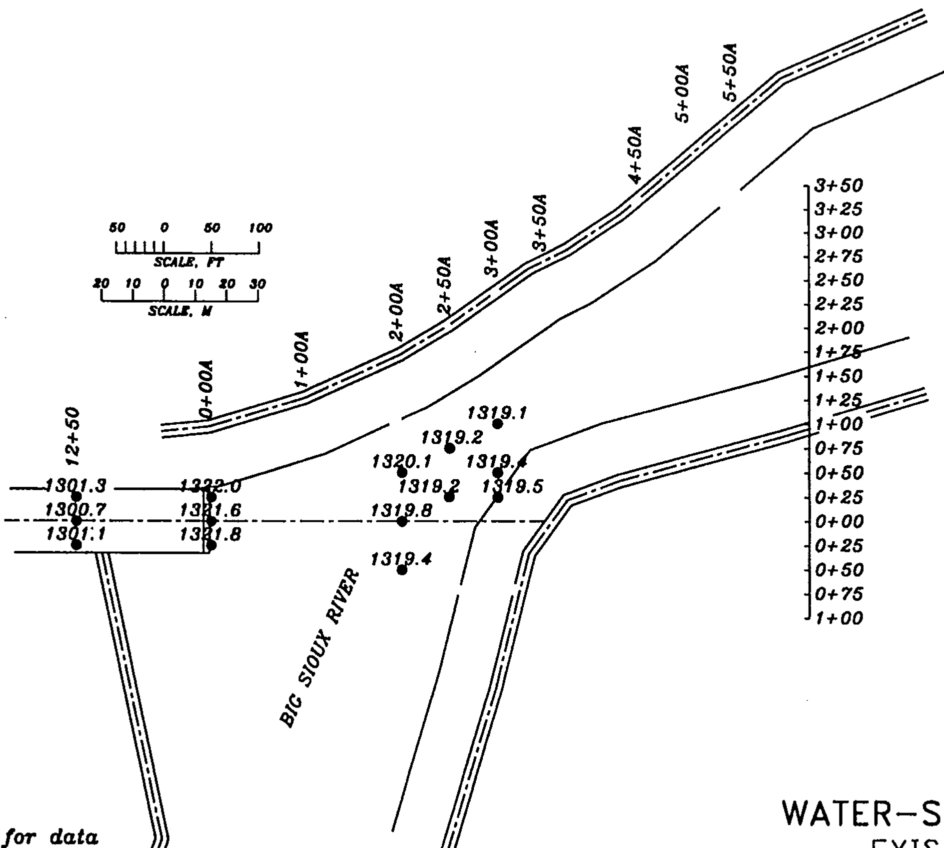
WATER–SURFACE ELEVATIONS

EXISTING CONDITIONS

Q_C = 356 CU M/SEC (12,700 CFS)

Q_R = 6 CU M/SEC (200 CFS)

TAILWATER ELEVATION 1315.0



Note: See Table 14 for data

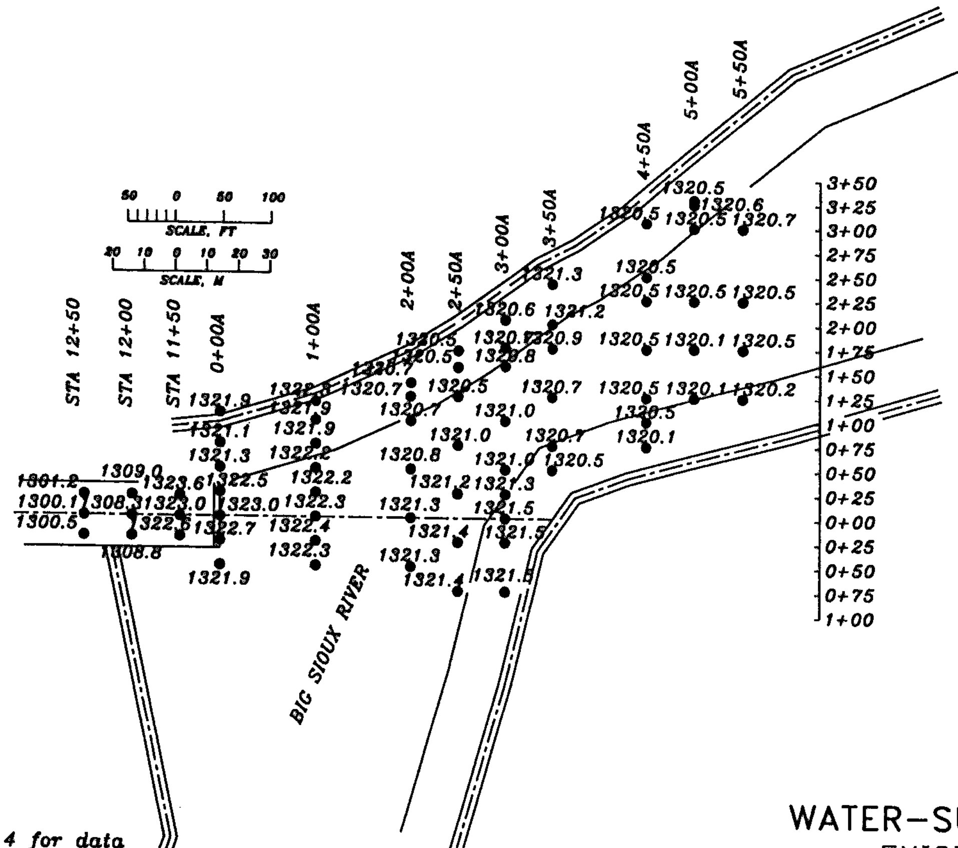
WATER–SURFACE ELEVATIONS

EXISTING CONDITIONS

Q_C = 591 CU M/SEC (21,100 CFS)

Q_R = 174 CU M/SEC (6,200 CFS)

TAILWATER ELEVATION 1318.0



Note: See Table 14 for data

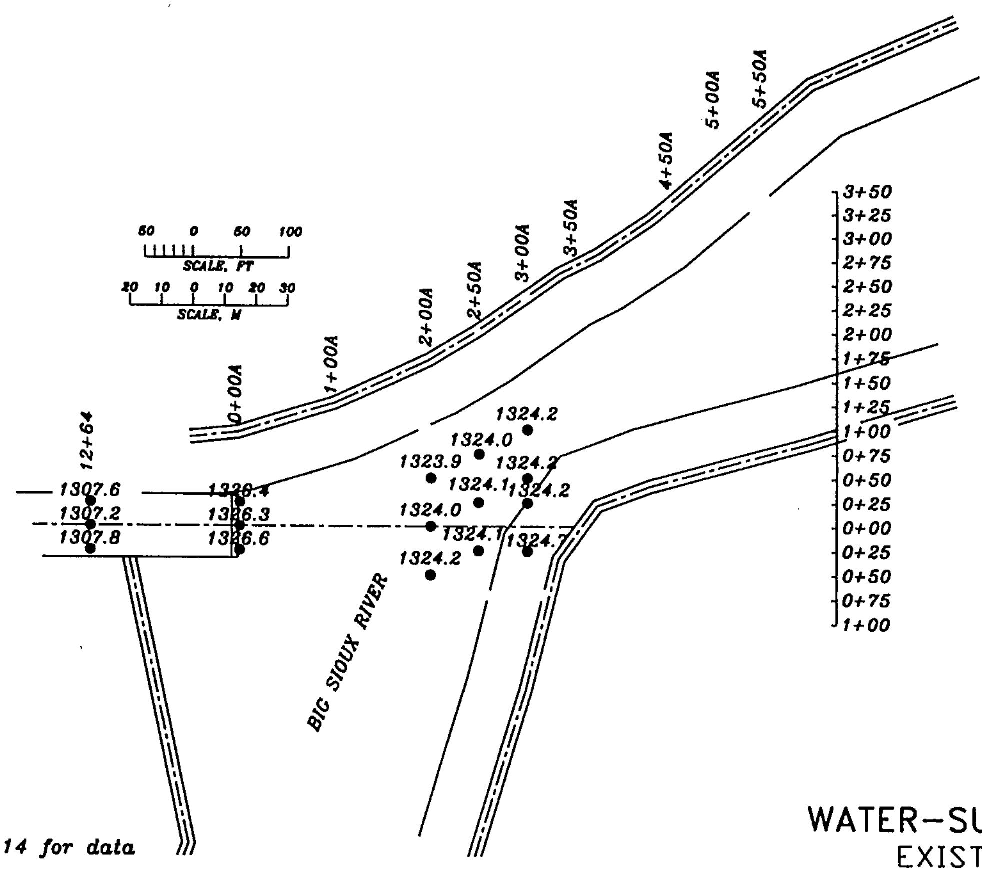
WATER–SURFACE ELEVATIONS

EXISTING CONDITIONS

Q_C = 591 CU M/SEC (21,100 CFS)

Q_R = 174 CU M/SEC (6,200 CFS)

TAILWATER ELEVATION 1320.2



Note: See Table 14 for data

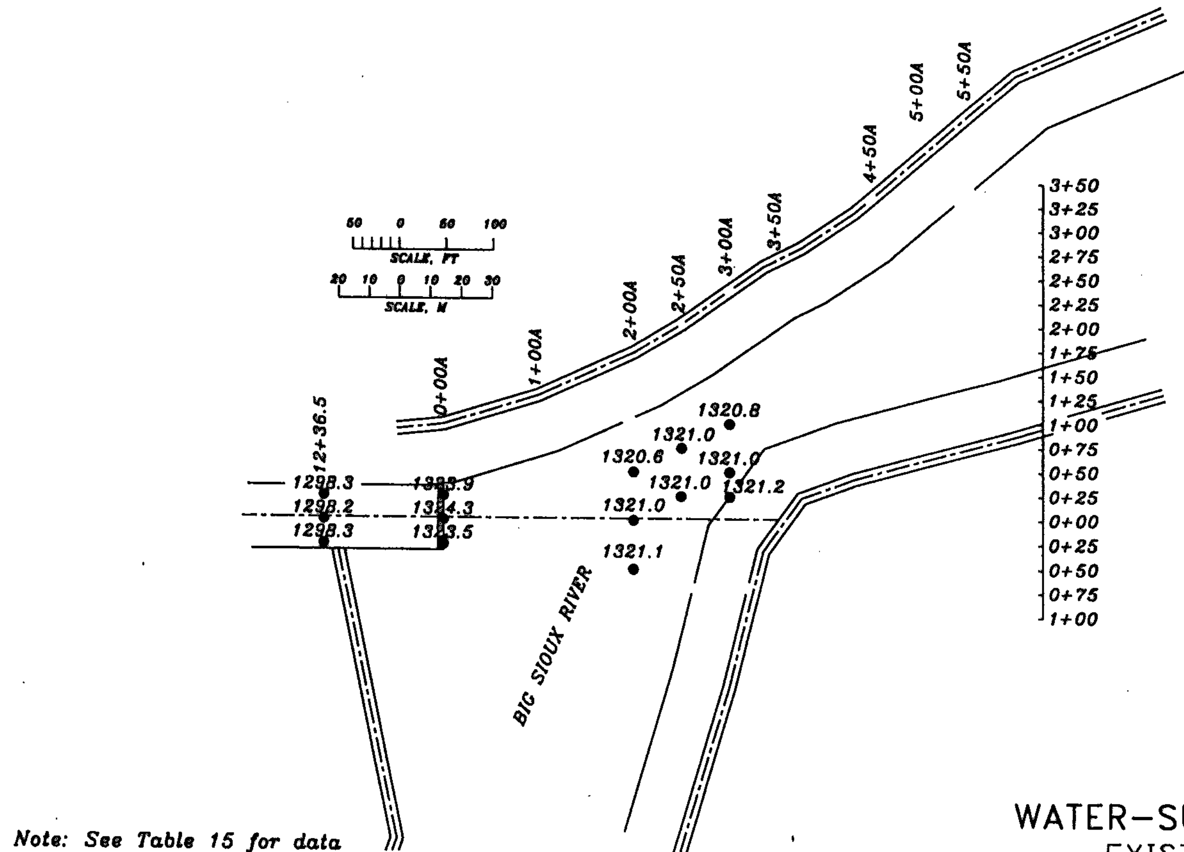
WATER–SURFACE ELEVATIONS

EXISTING CONDITIONS

Q_C = 591 CU M/SEC (21,100 CFS)

Q_R = 174 CU M/SEC (6,200 CFS)

TAILWATER ELEVATION 1324.0



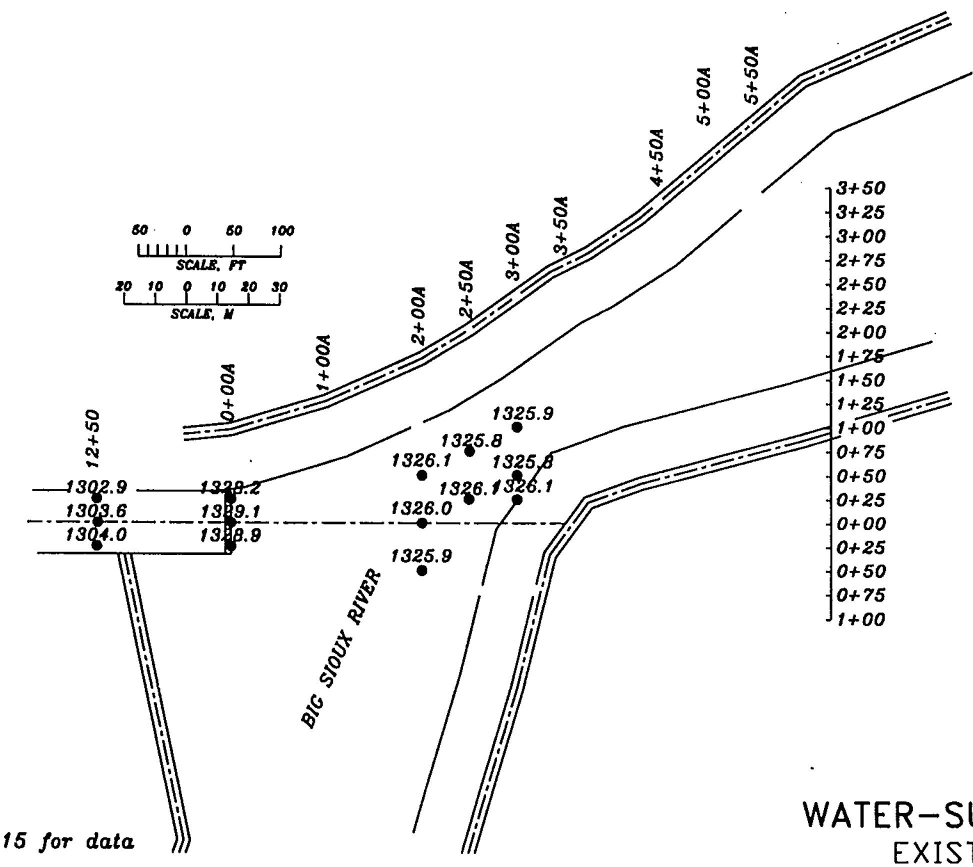
WATER–SURFACE ELEVATIONS

EXISTING CONDITIONS

Q_C = 700 CU M/SEC (25,000 CFS)

Q_R = 224 CU M/SEC (8,000 CFS)

TAILWATER ELEVATION 1320.0



Note: See Table 15 for data

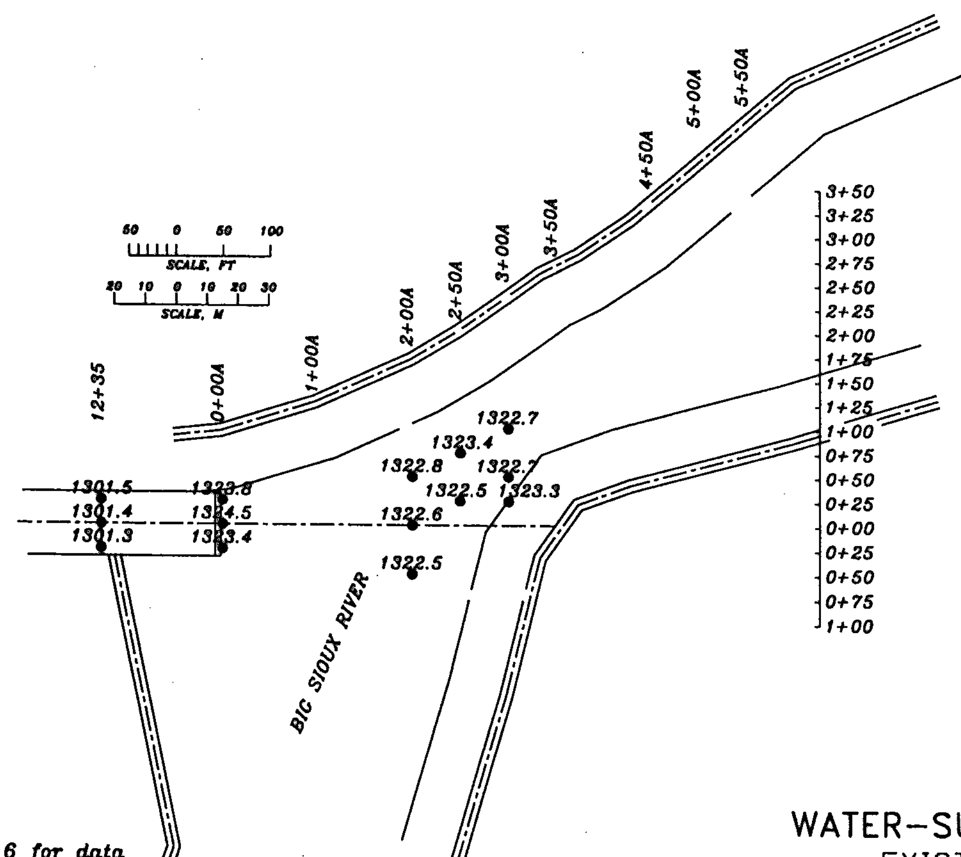
WATER–SURFACE ELEVATIONS

EXISTING CONDITIONS

Q_C = 700 CU M/SEC (25,000 CFS)

Q_R = 224 CU M/SEC (8,000 CFS)

TAILWATER ELEVATION 1326.0



Note: See Table 16 for data

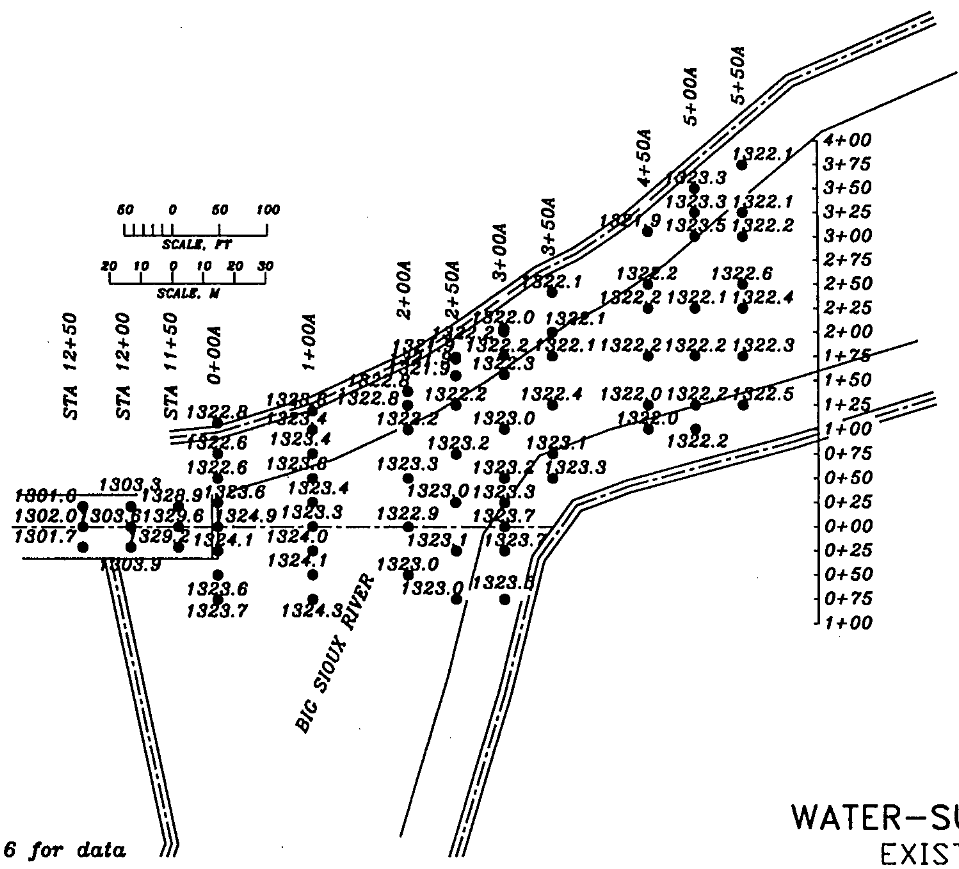
WATER–SURFACE ELEVATIONS

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 204 CU M/SEC (7,300 CFS)

TAILWATER ELEVATION 1322.0



Note: See Table 16 for data

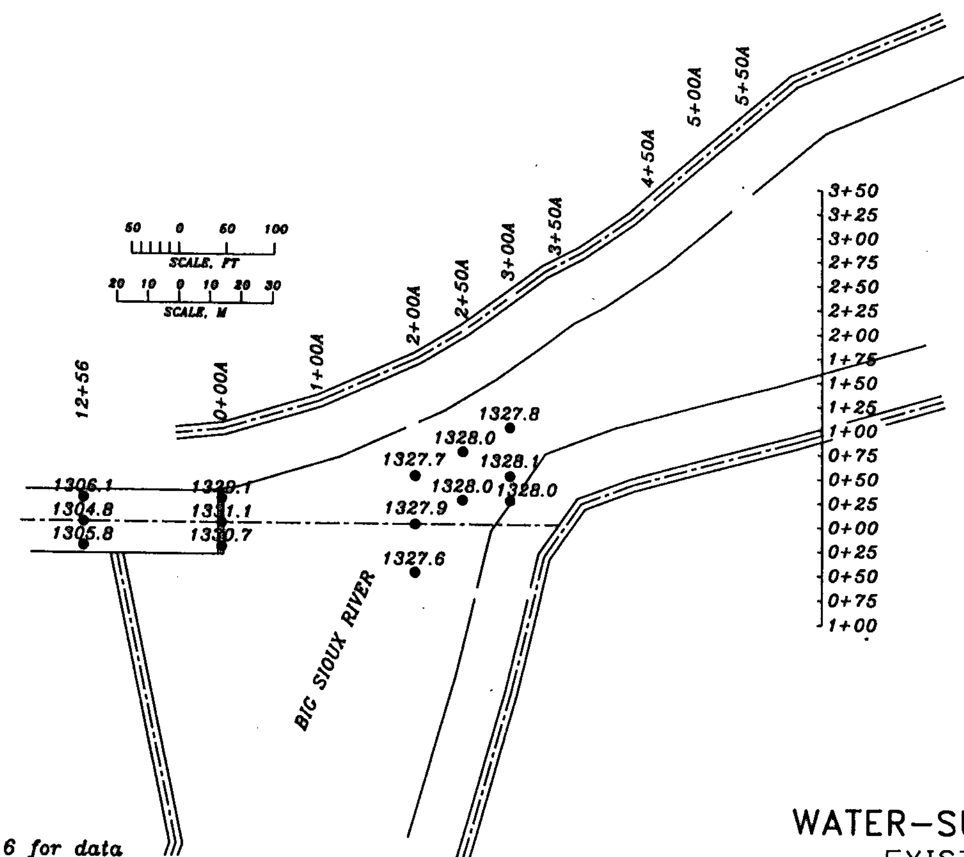
WATER–SURFACE ELEVATIONS

EXISTING CONDITIONS

Q_C= 812 CU M/SEC (29,000 CFS)

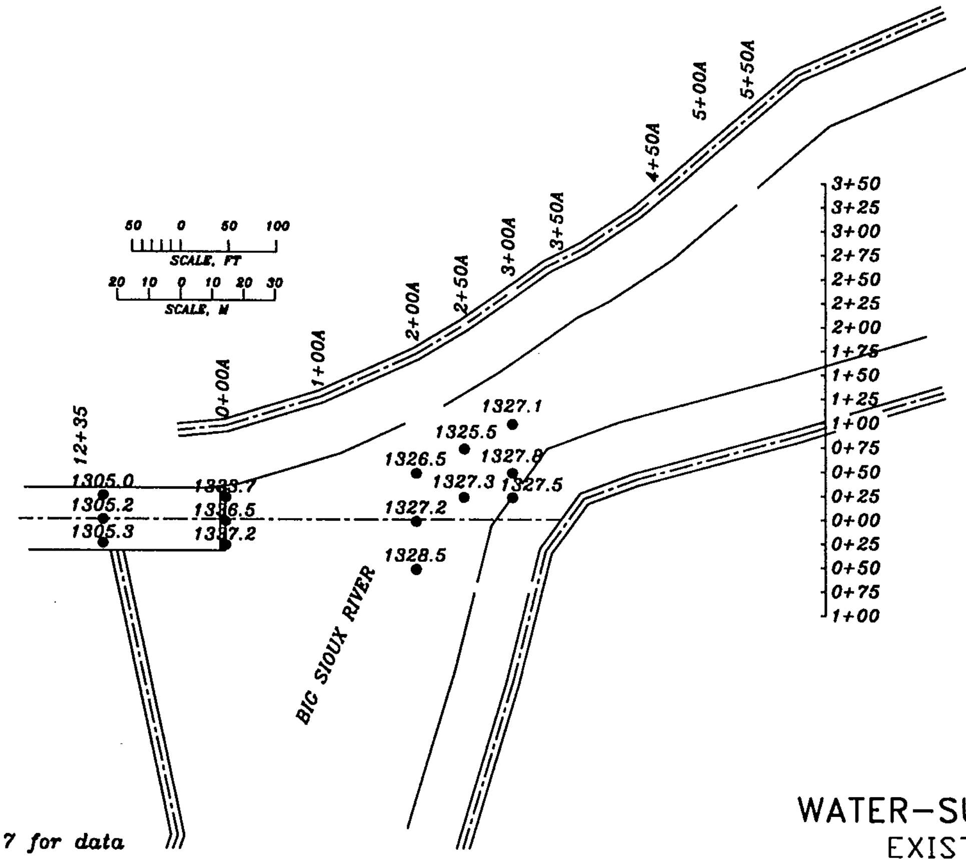
Q_R= 204 CU M/SEC (7,300 CFS)

TAILWATER ELEVATION 1322.5



Note: See Table 16 for data

WATER–SURFACE ELEVATIONS
EXISTING CONDITIONS
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 204 CU M/SEC (7,300 CFS)
TAILWATER ELEVATION 1328.0



Note: See Table 17 for data

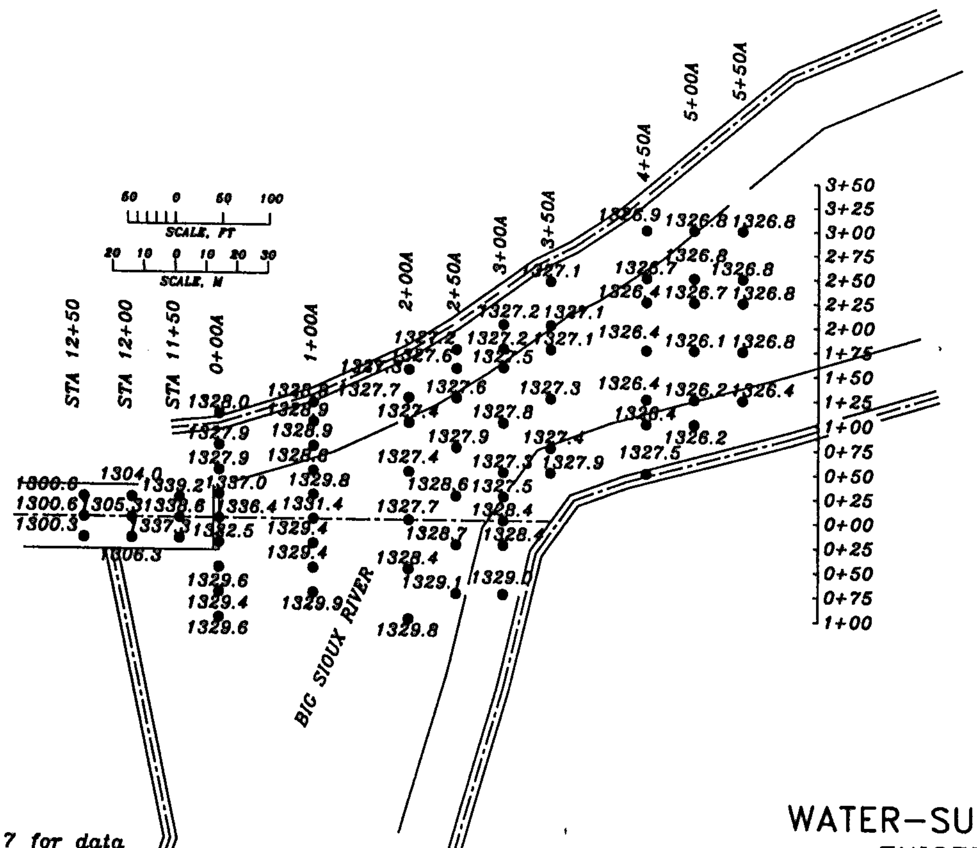
WATER–SURFACE ELEVATIONS

EXISTING CONDITIONS

Q_C= 1,044 CU M/SEC (37,300 CFS)

Q_R= 812 CU M/SEC (29,000 CFS)

TAILWATER ELEVATION 1326.0



Note: See Table 17 for data

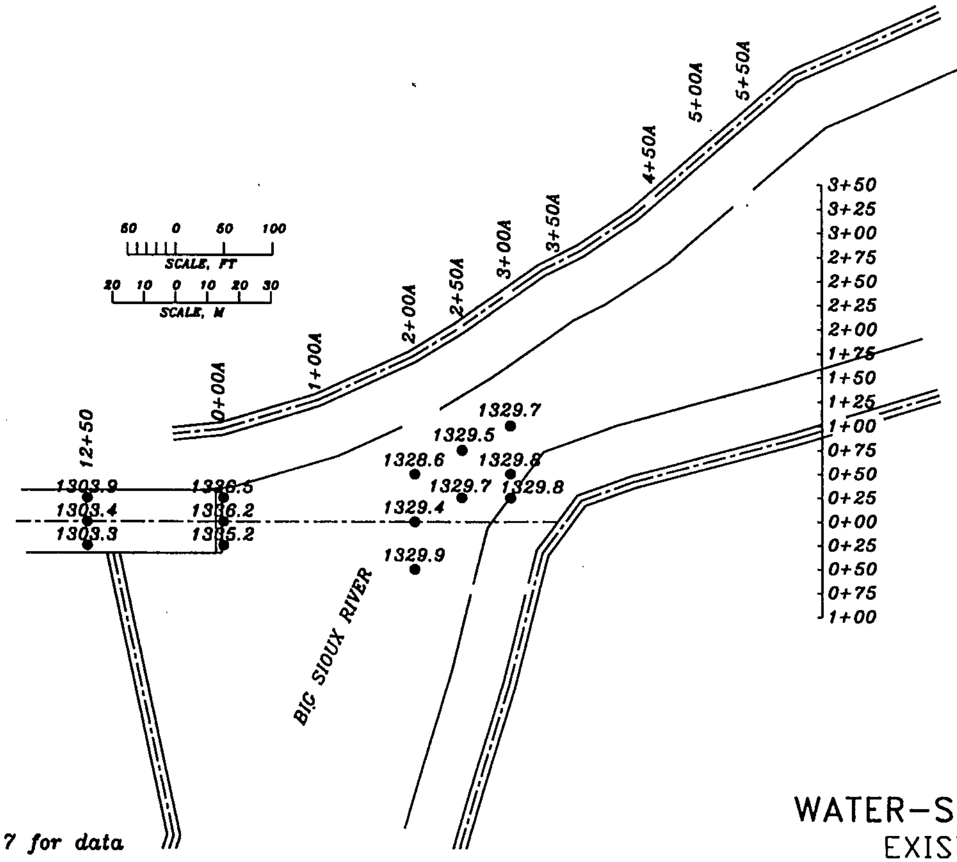
WATER–SURFACE ELEVATIONS

EXISTING CONDITIONS

Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

TAILWATER ELEVATION 1327.0



Note: See Table 17 for data

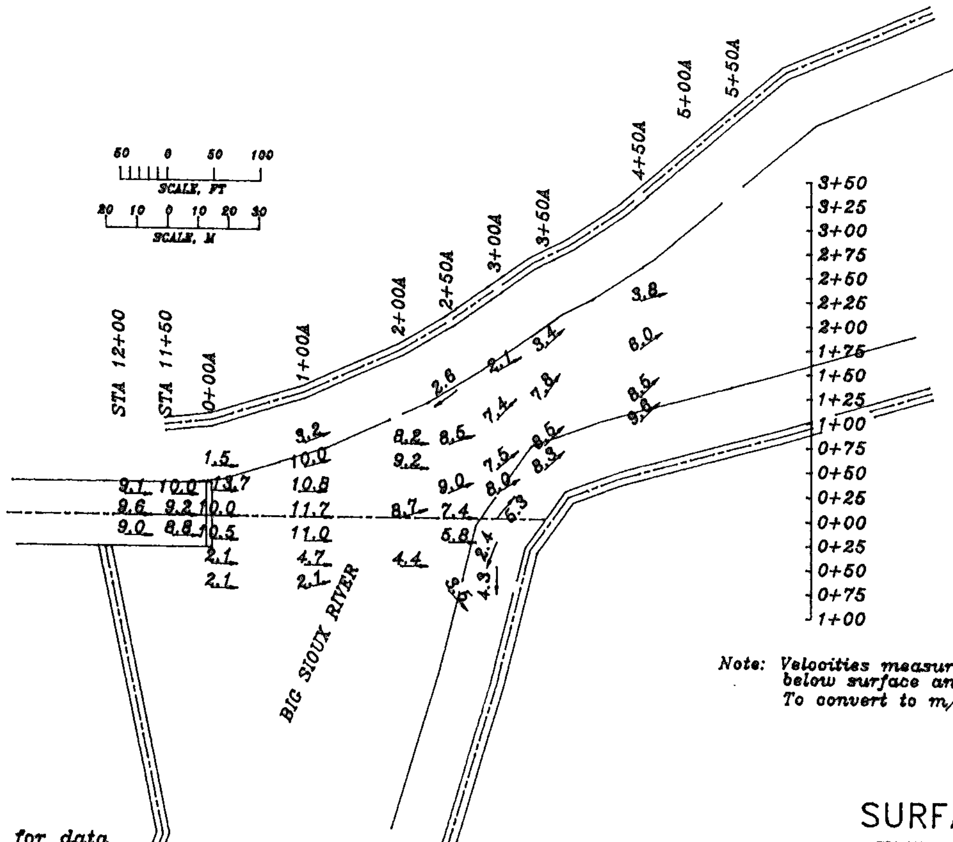
WATER-SURFACE ELEVATIONS

EXISTING CONDITIONS

Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

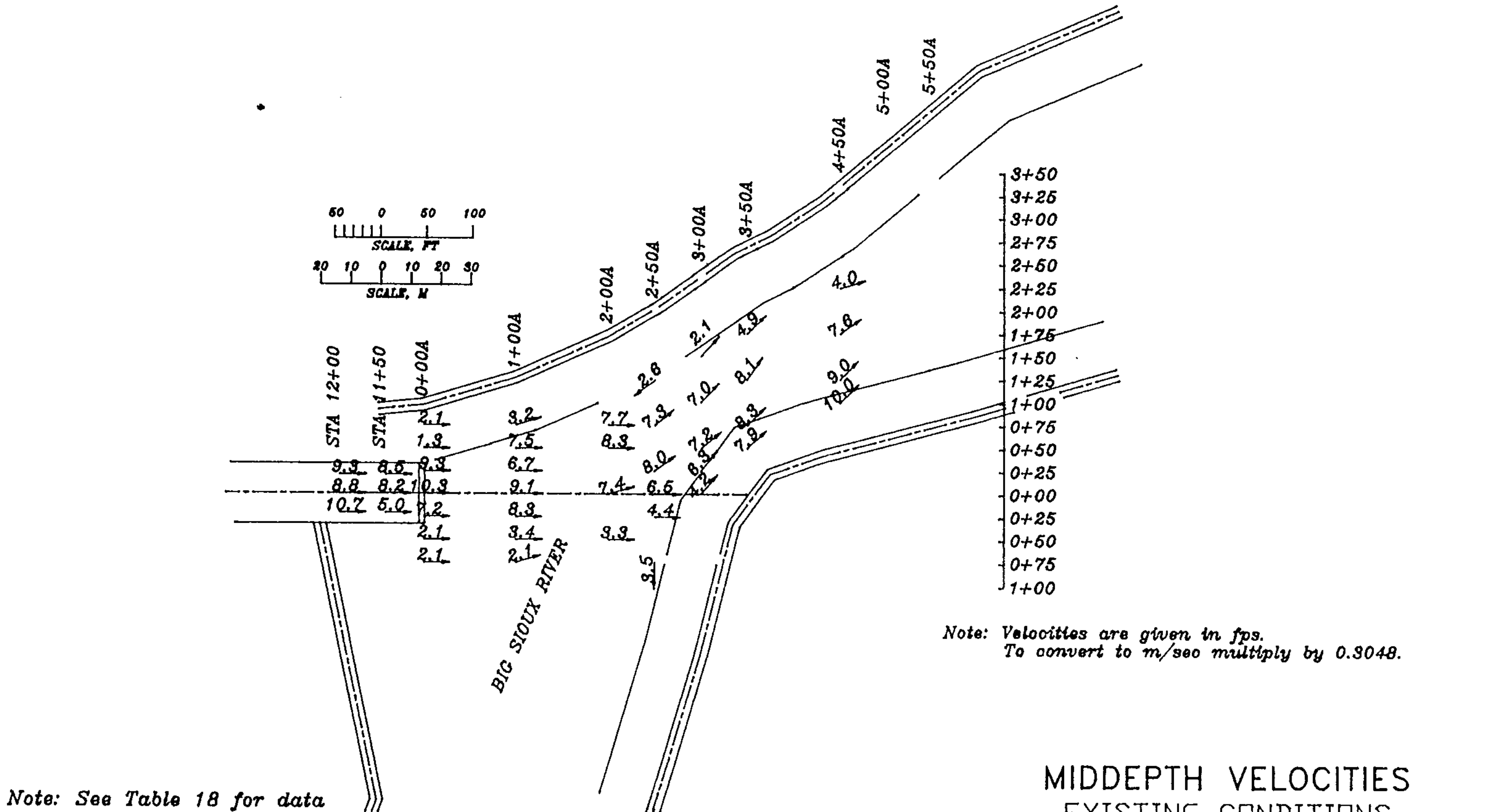
TAILWATER ELEVATION 1330.0



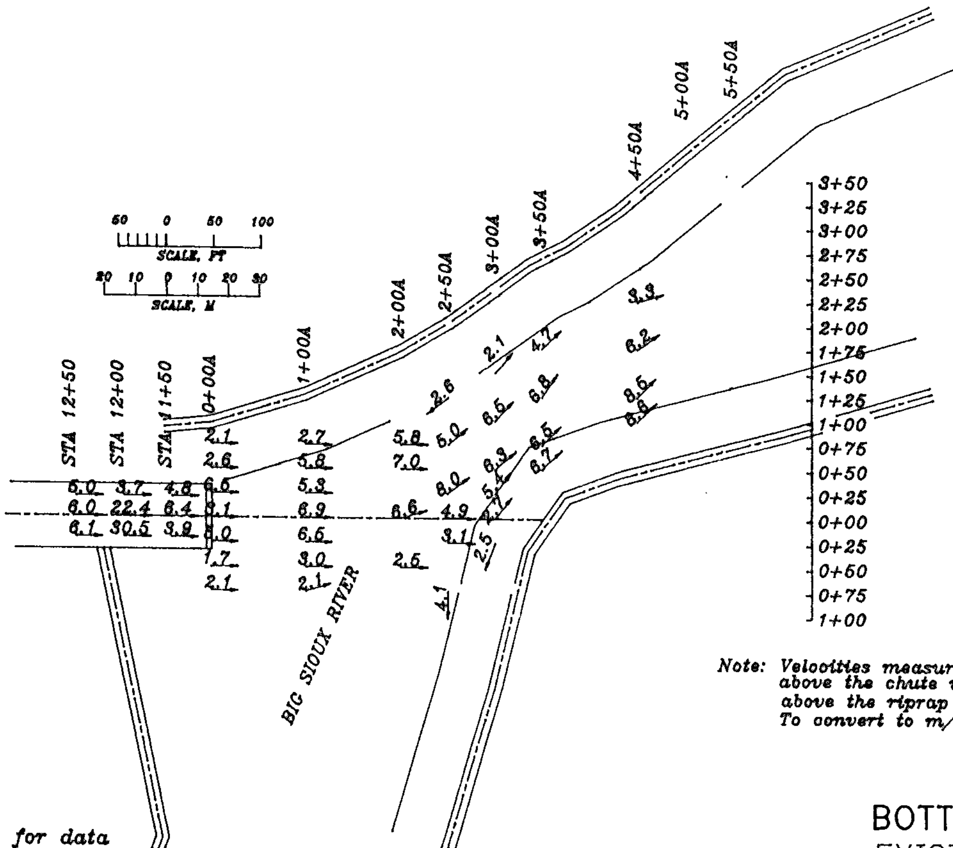
Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 18 for data

SURFACE VELOCITIES
EXISTING CONDITIONS
Q_C = 356 CU M/SEC (12,700 CFS)
Q_R = 6 CU M/SEC (200 CFS)
TAILWATER ELEVATION 1315.0



MIDDEPTH VELOCITIES
EXISTING CONDITIONS
Q_C = 356 CU M/SEC (12,700 CFS)
Q_R = 6 CU M/SEC (200 CFS)
TAILWATER ELEVATION 1315.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 18 for data

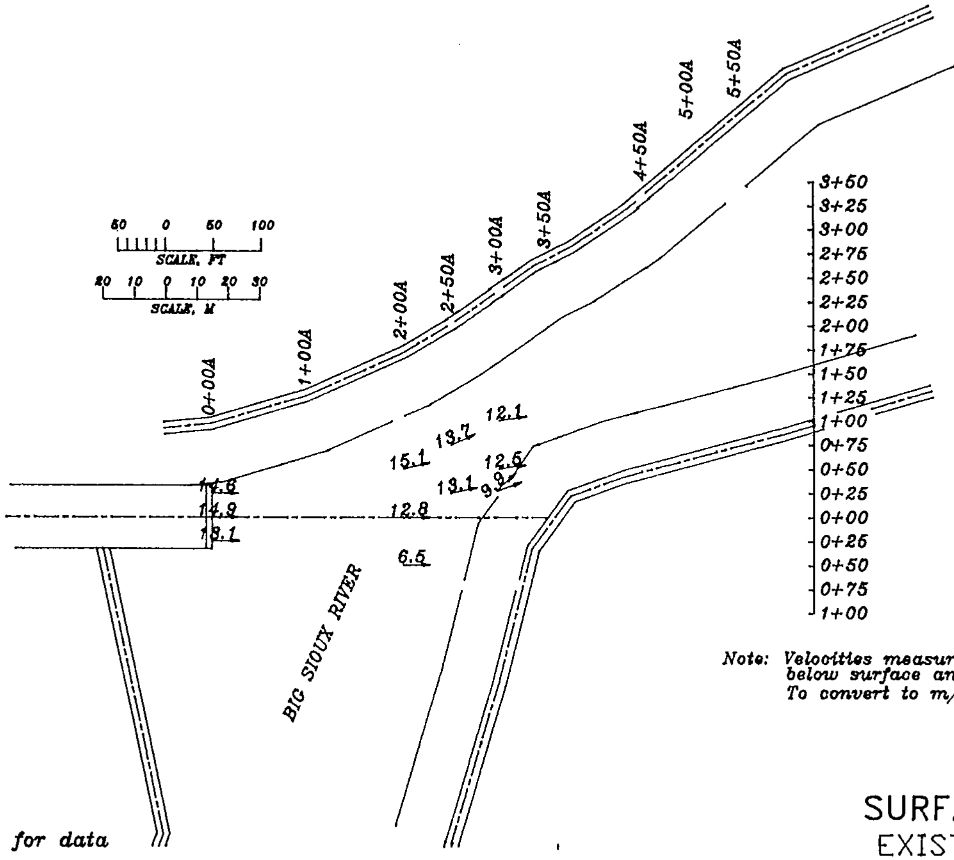
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 356 CU M/SEC (12,700 CFS)

Q_R = 6 CU M/SEC (200 CFS)

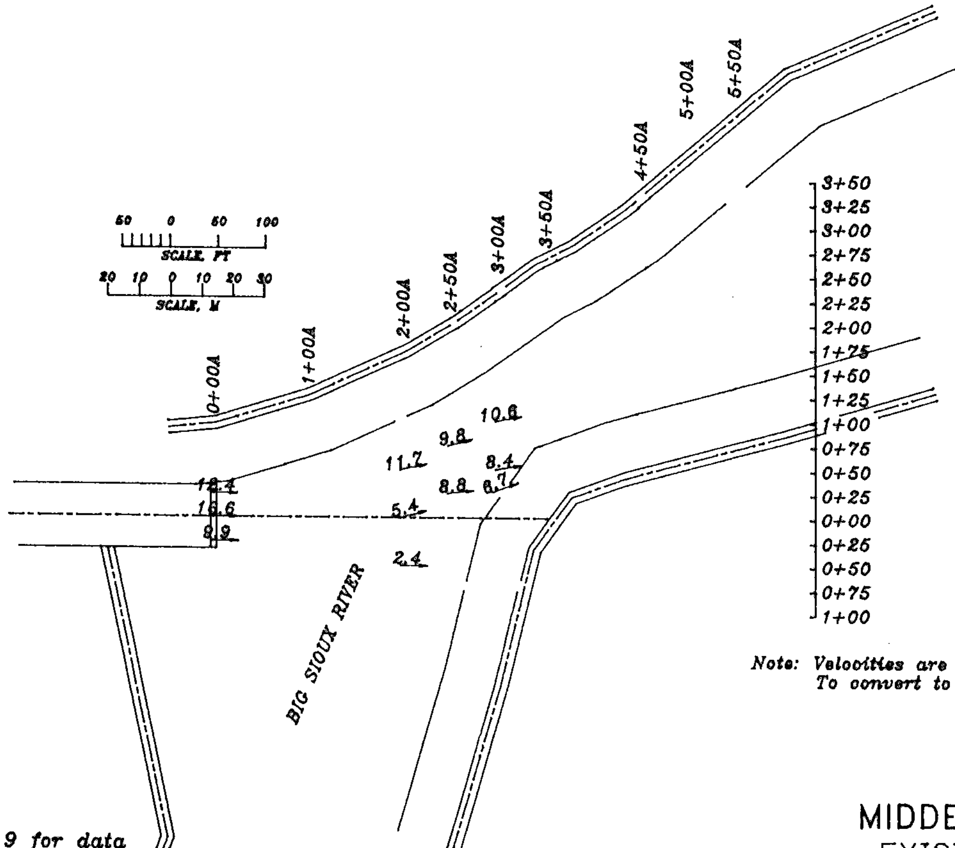
TAILWATER ELEVATION 1315.0



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 19 for data

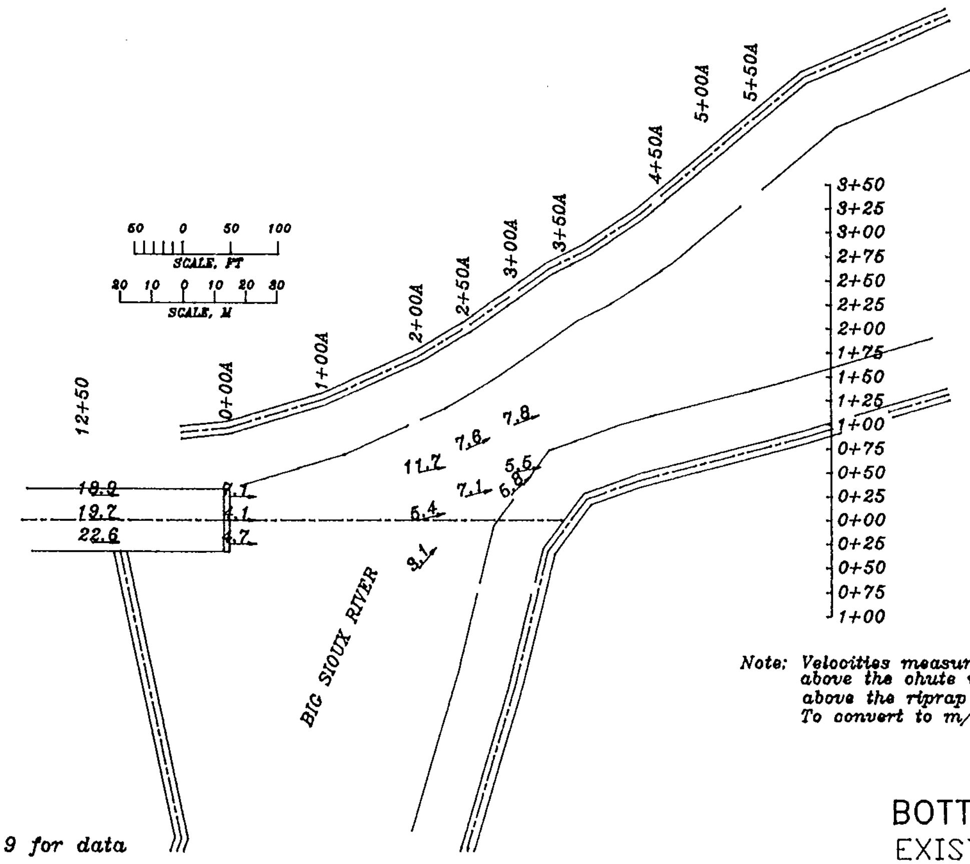
SURFACE VELOCITIES
EXISTING CONDITIONS
Q_C = 591 CU M/SEC (21,100 CFS)
Q_R = 174 CU M/SEC (6,200 CFS)
TAILWATER ELEVATION 1318.0



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 19 for data

MIDDEPTH VELOCITIES
EXISTING CONDITIONS
Q_C = 591 CU M/SEC (21,100 CFS)
Q_R = 174 CU M/SEC (6,200 CFS)
TAILWATER ELEVATION 1318.0



Note: See Table 19 for data

Note: *Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.*

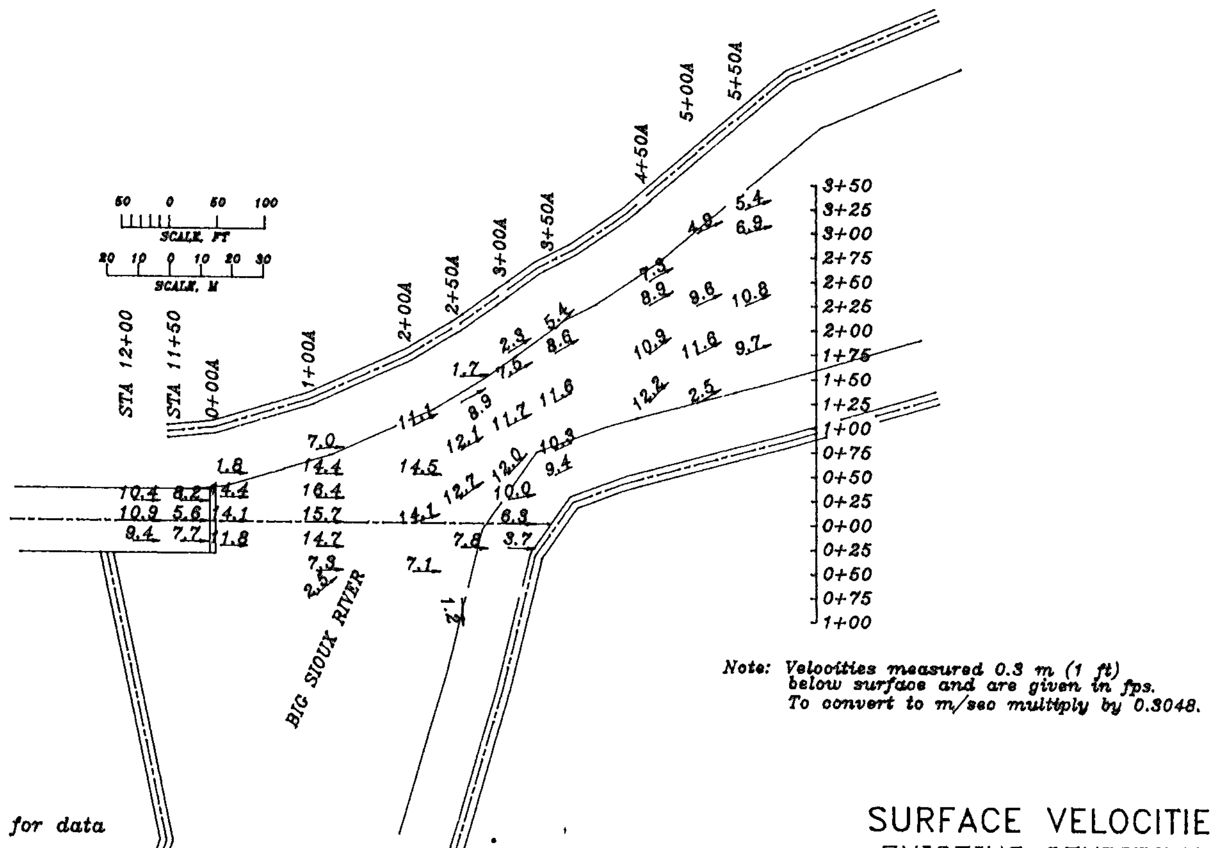
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 591 CU M/SEC (21,100 CFS)

Q_R = 174 CU M/SEC (6,200 CFS)

TAILWATER ELEVATION 1318.0



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

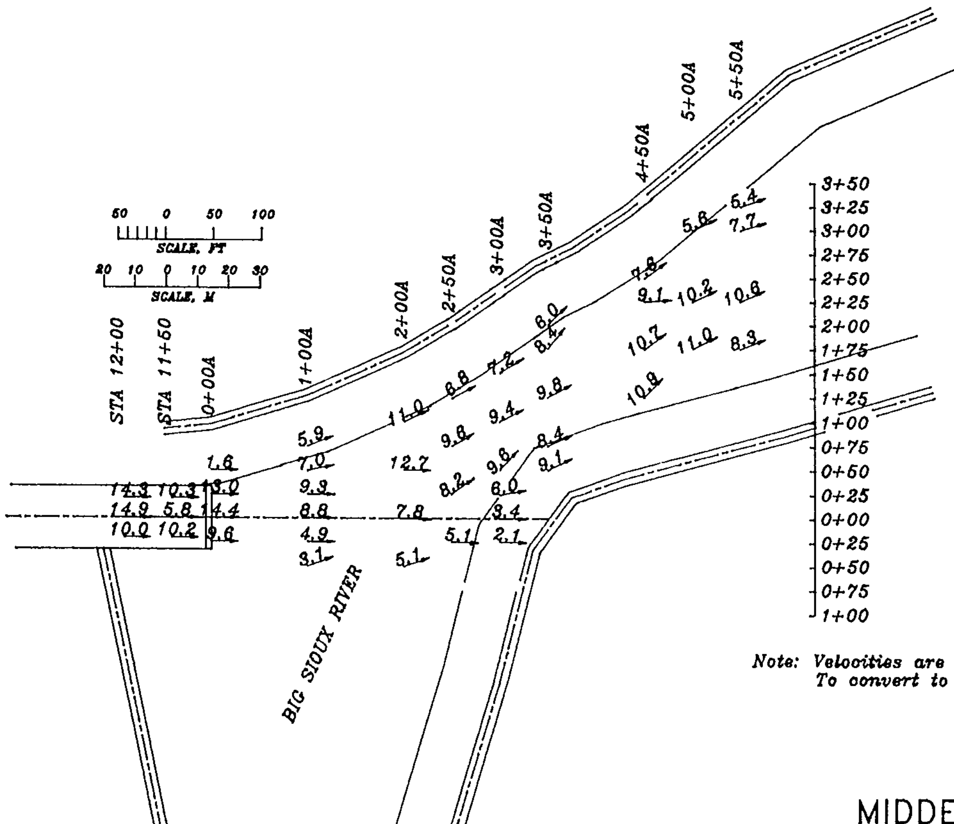
Note: See Table 20 for data

SURFACE VELOCITIES
EXISTING CONDITIONS

Q_C = 591 CU M/SEC (21,100 CFS)

Q_R = 174 CU M/SEC (6,200 CFS)

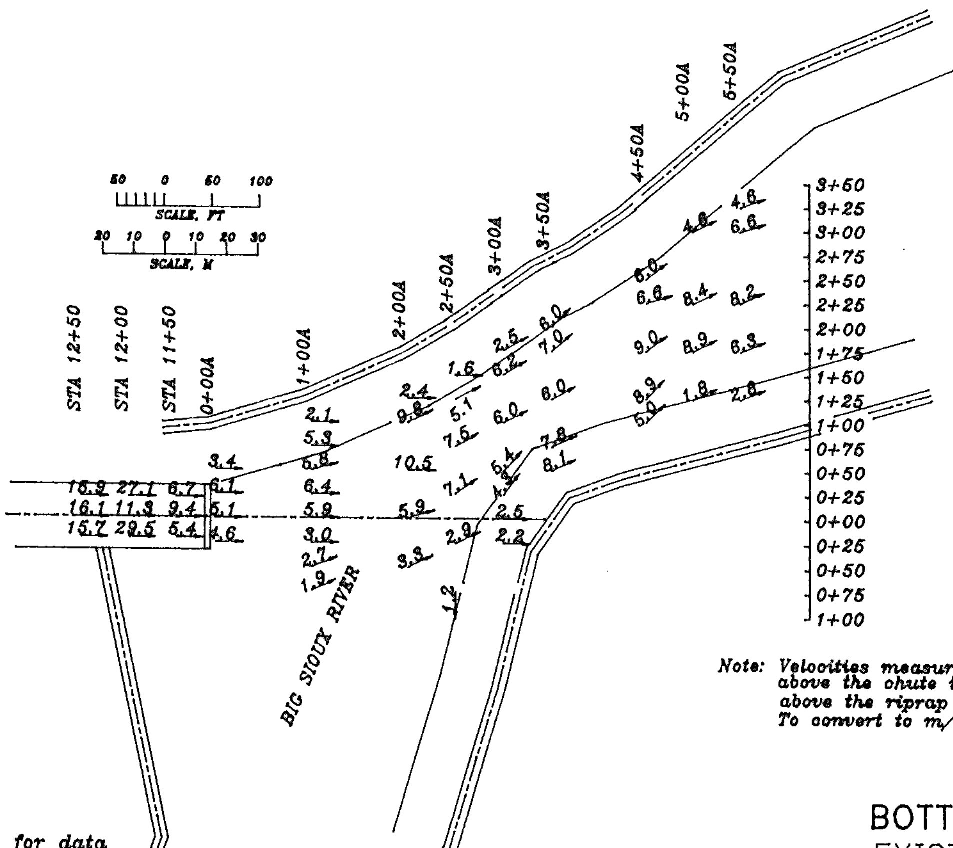
TAILWATER ELEVATION 1320.2



Note: See Table 20 for data

Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

MIDDEPTH VELOCITIES
EXISTING CONDITIONS
Q_C =591 CU M/SEC (21,100 CFS)
Q_R= 174 CU M/SEC (6,200 CFS)
TAILWATER ELEVATION 1320.2



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 20 for data

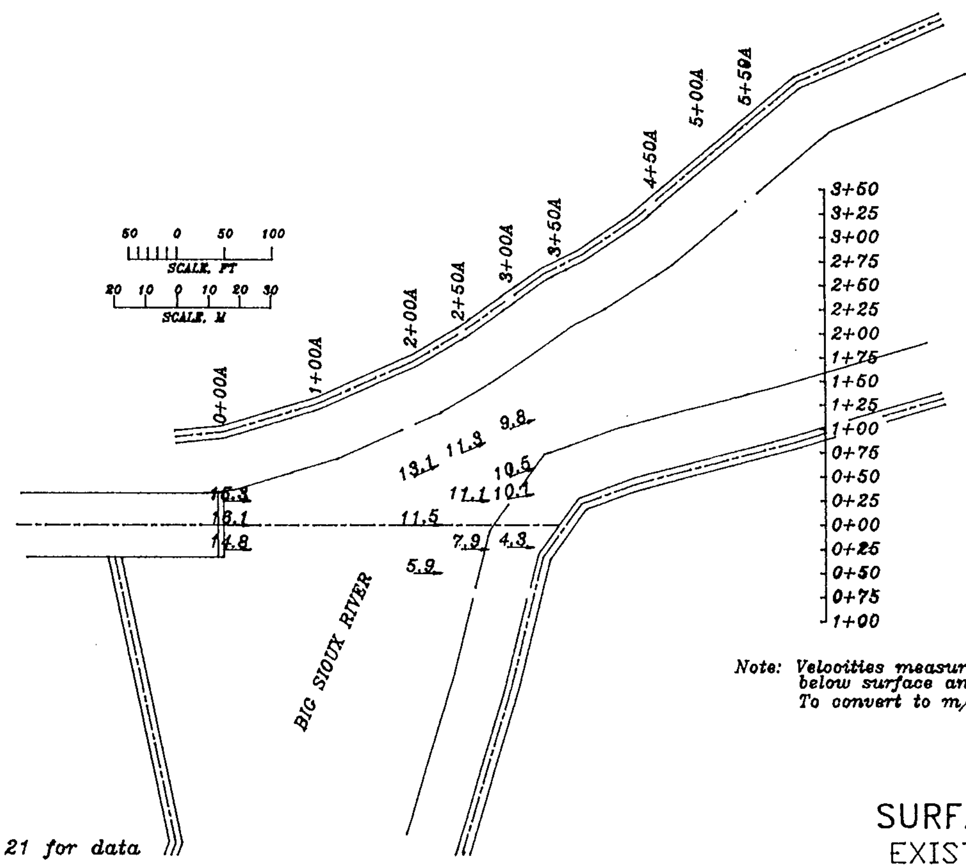
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 591 CU M/SEC (21,100 CFS)

Q_R = 174 CU M/SEC (6,200 CFS)

TAILWATER ELEVATION 1320.2



Note: See Table 21 for data

Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

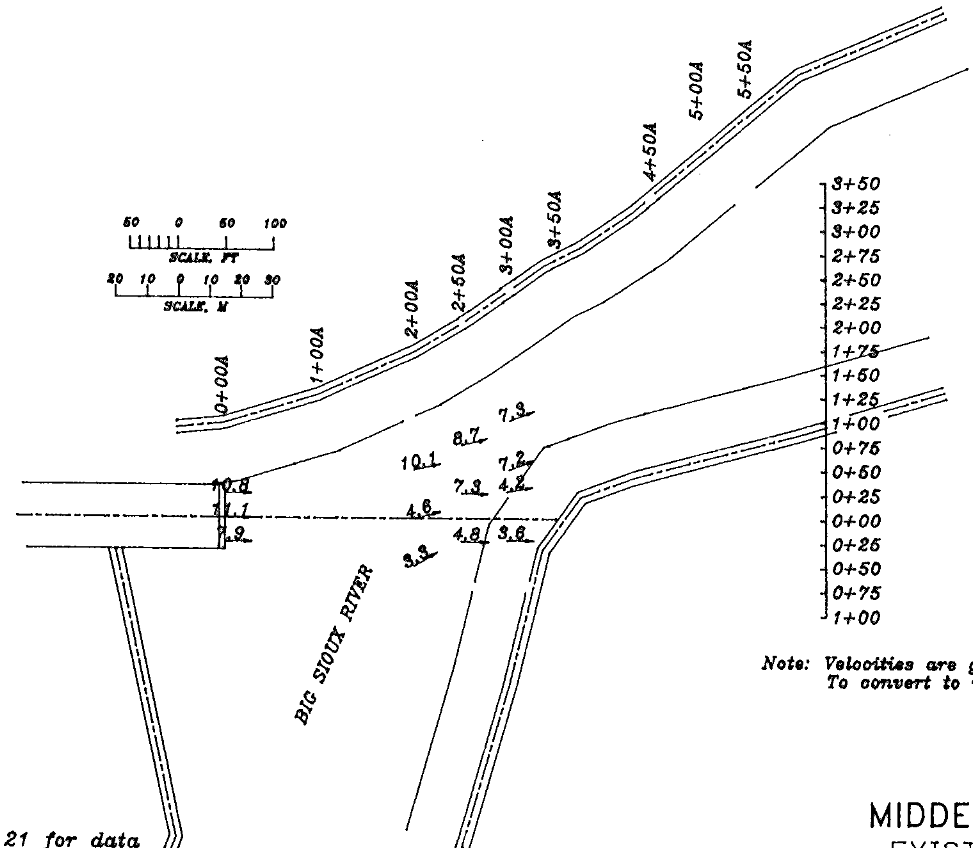
SURFACE VELOCITIES

EXISTING CONDITIONS

Q_C = 591 CU M/SEC (21,100 CFS)

Q_R = 174 CU M/SEC (6,200 CFS)

TAILWATER ELEVATION 1324.0



Note: See Table 21 for data

Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

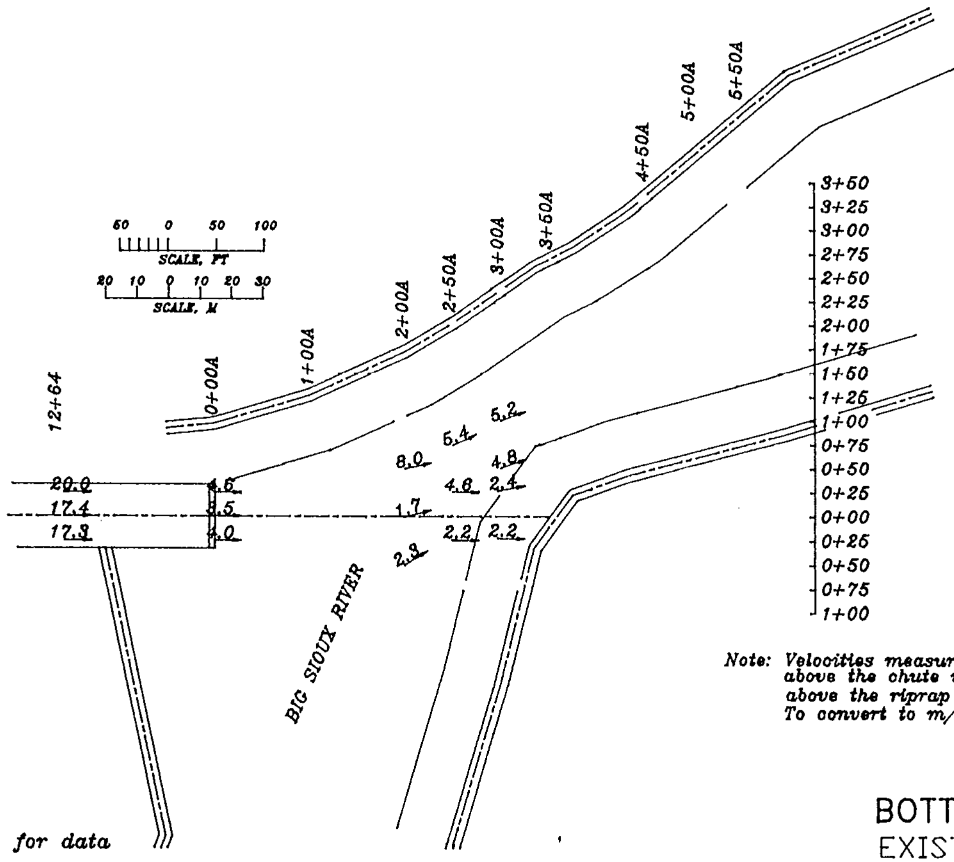
MIDDEPTH VELOCITIES

EXISTING CONDITIONS

Q_C = 591 CU M/SEC (21,100 CFS)

Q_R = 174 CU M/SEC (6,200 CFS)

TAILWATER ELEVATION 1324.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 21 for data

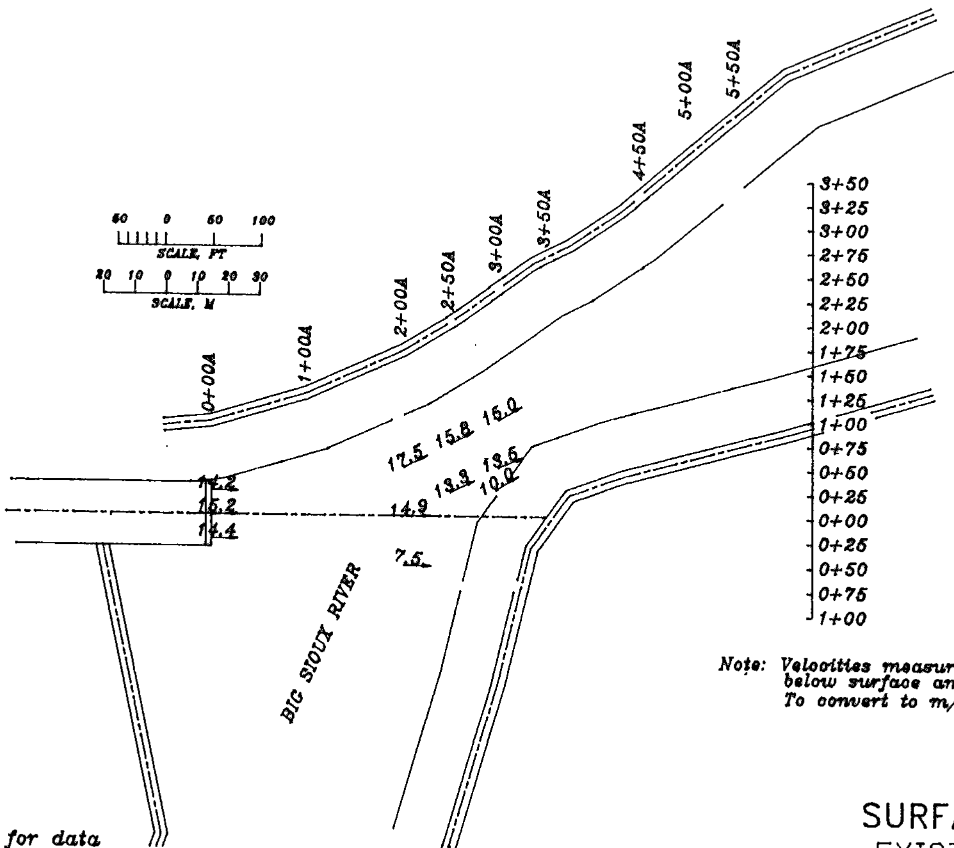
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 591 CU M/SEC (21,100 CFS)

Q_R = 174 CU M/SEC (6,200 CFS)

TAILWATER ELEVATION 1324.0



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 22 for data

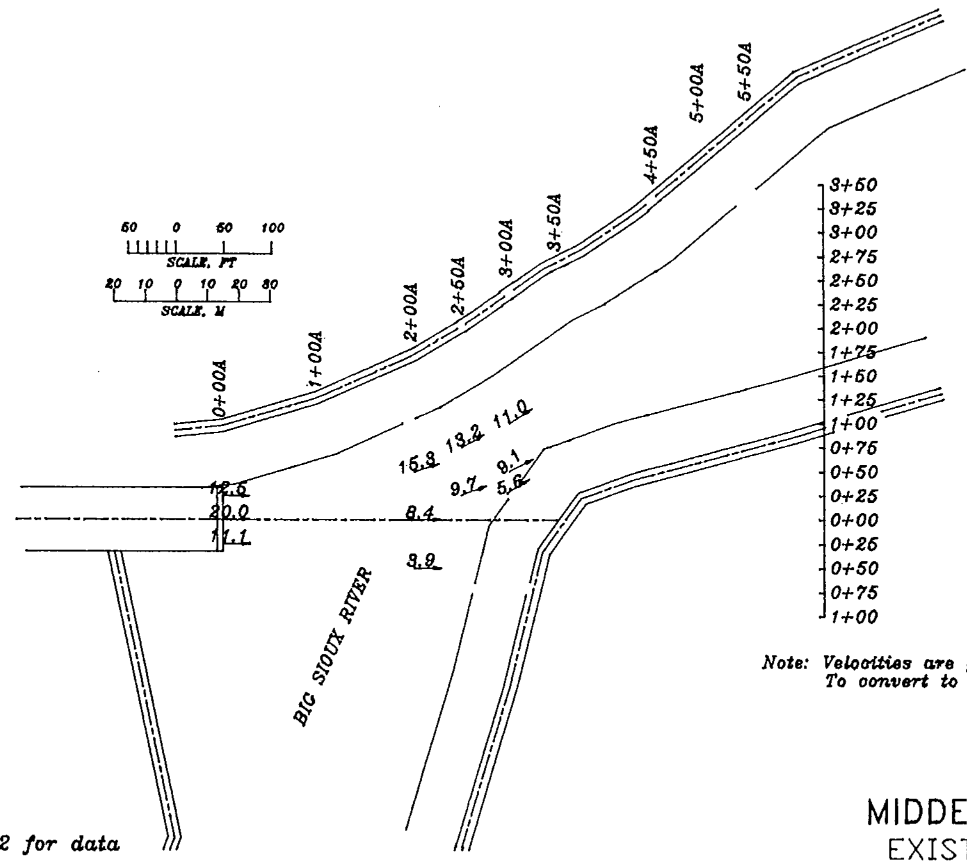
SURFACE VELOCITIES

EXISTING CONDITIONS

Q_C = 700 CU M/SEC (25,000 CFS)

Q_R = 224 CU M/SEC (8,000 CFS)

TAILWATER ELEVATION 1320.0



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 22 for data

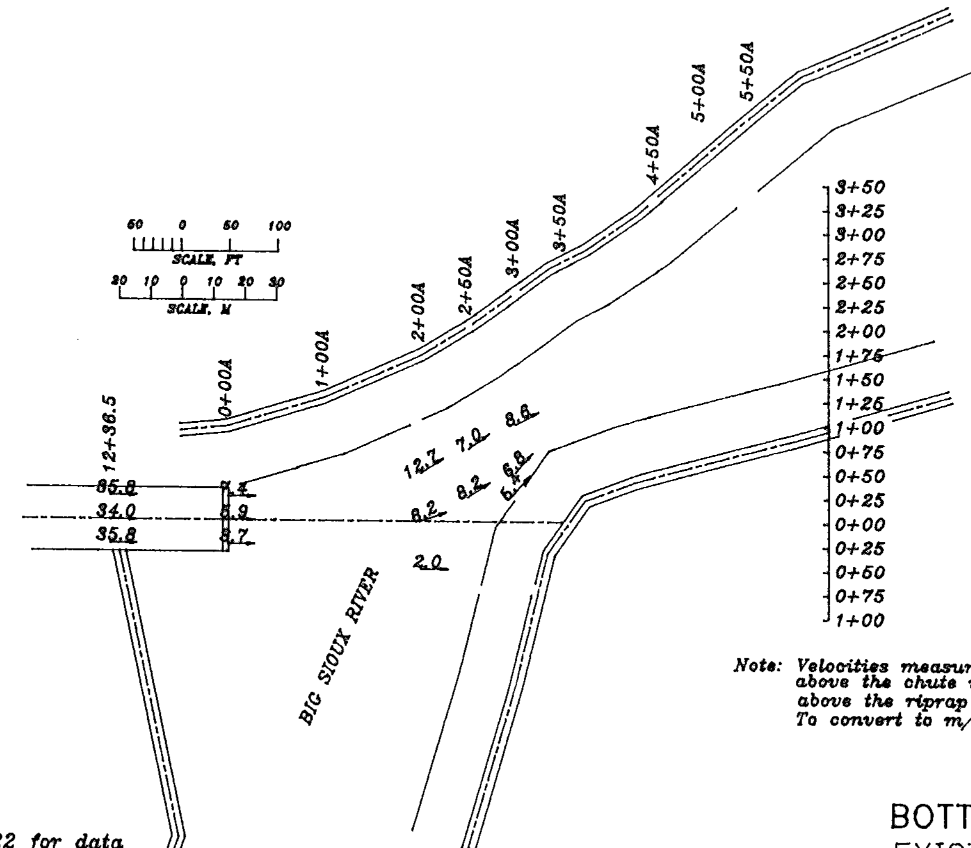
MIDDEPTH VELOCITIES

EXISTING CONDITIONS

Q_C = 700 CU M/SEC (25,000 CFS)

Q_R =224 CU M/SEC (8,000 CFS)

TAILWATER ELEVATION 1320.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 22 for data

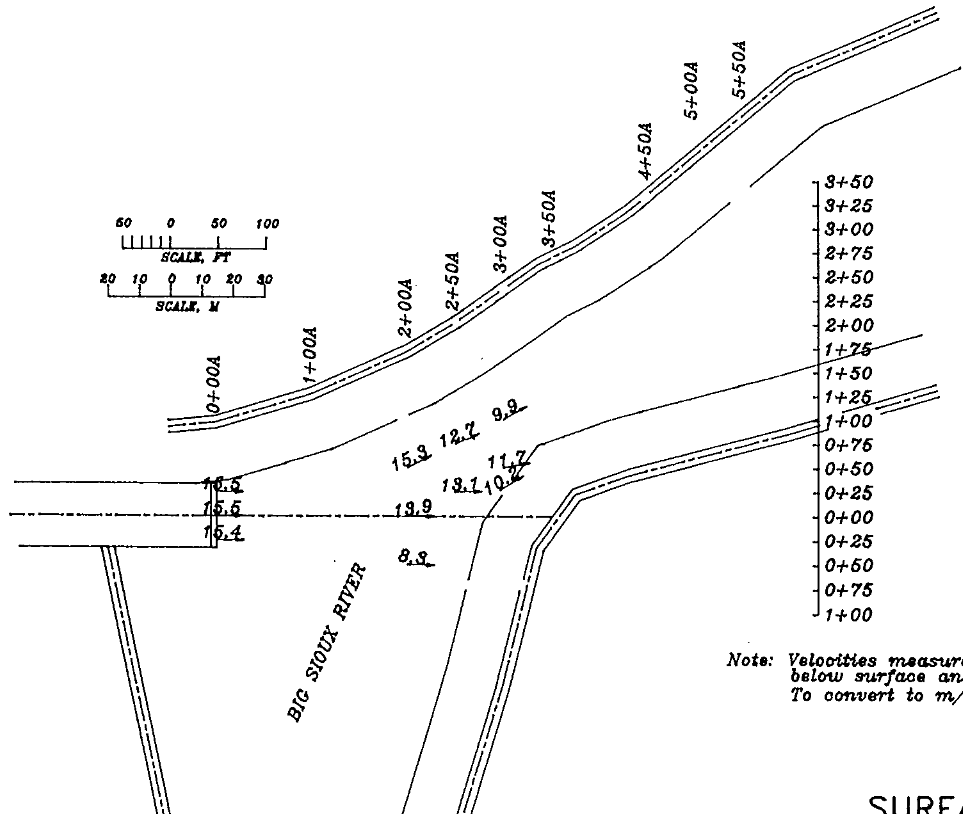
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 700 CU M/SEC (25,000 CFS)

Q_R = 224 CU M/SEC (8,000 CFS)

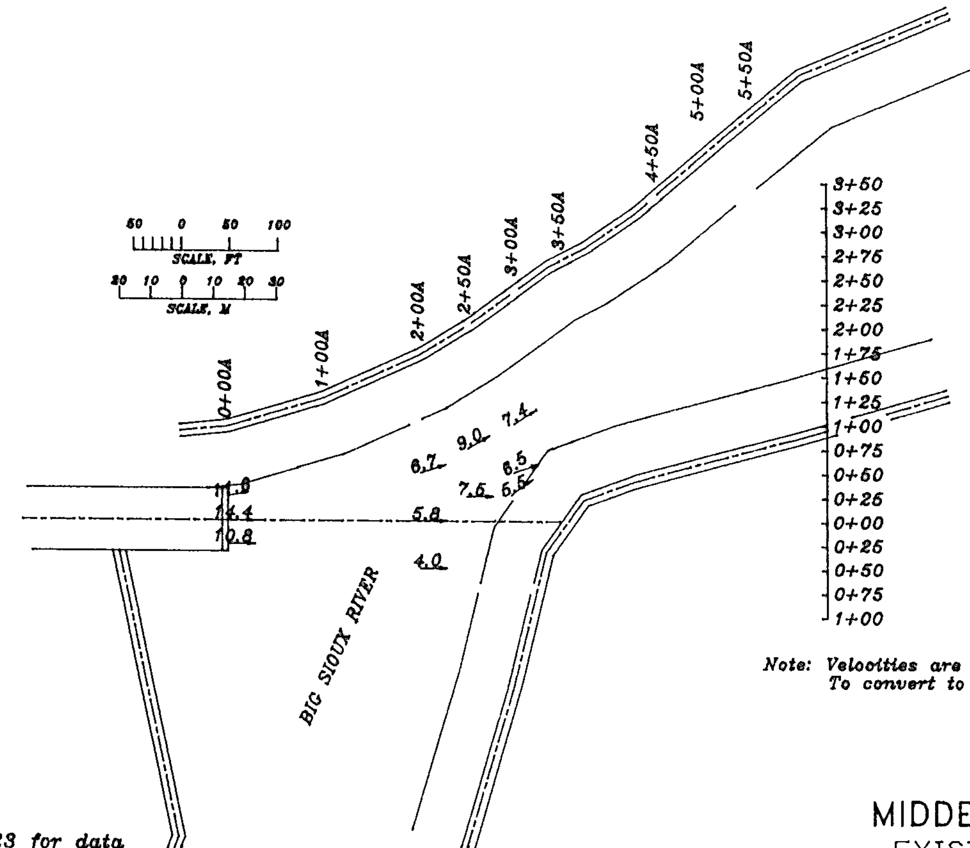
TAILWATER ELEVATION 1320.0



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 23 for data

SURFACE VELOCITIES
EXISTING CONDITIONS
Q_C = 700 CU M/SEC (25,000 CFS)
Q_R = 224 CU M/SEC (8,000 CFS)
TAILWATER ELEVATION 1326.0



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 23 for data

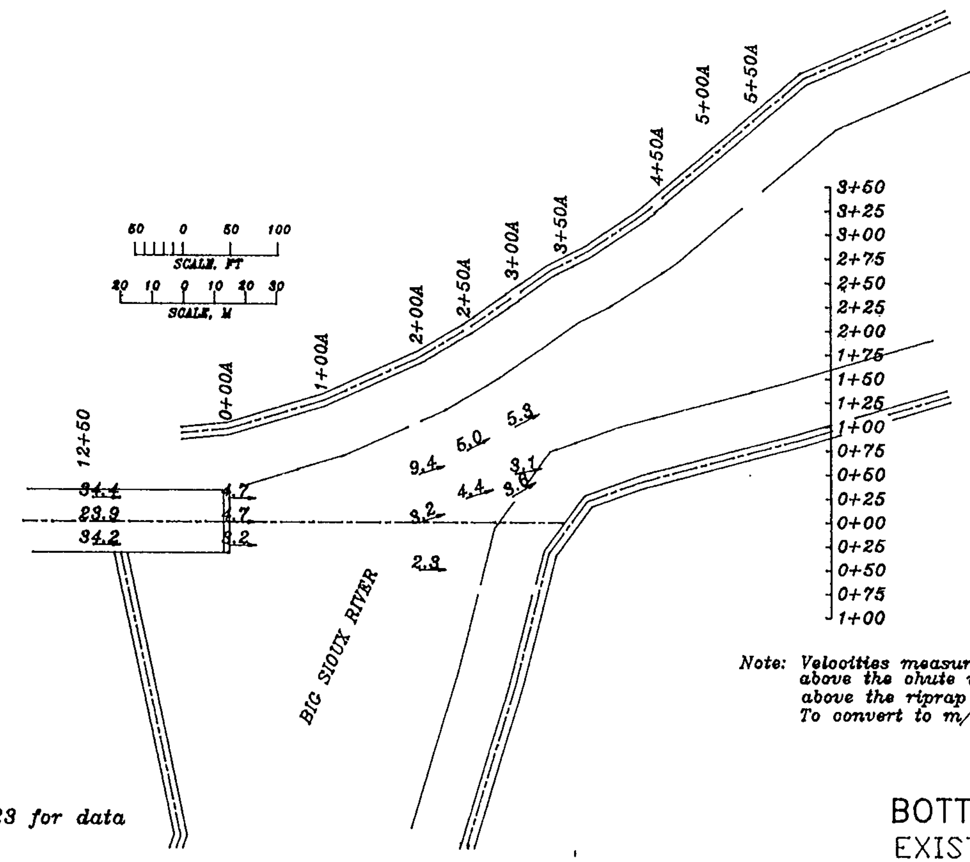
MIDDEPTH VELOCITIES

EXISTING CONDITIONS

Q_C = 700 CU M/SEC (25,000 CFS)

Q_R =224 CU M/SEC (8,000 CFS)

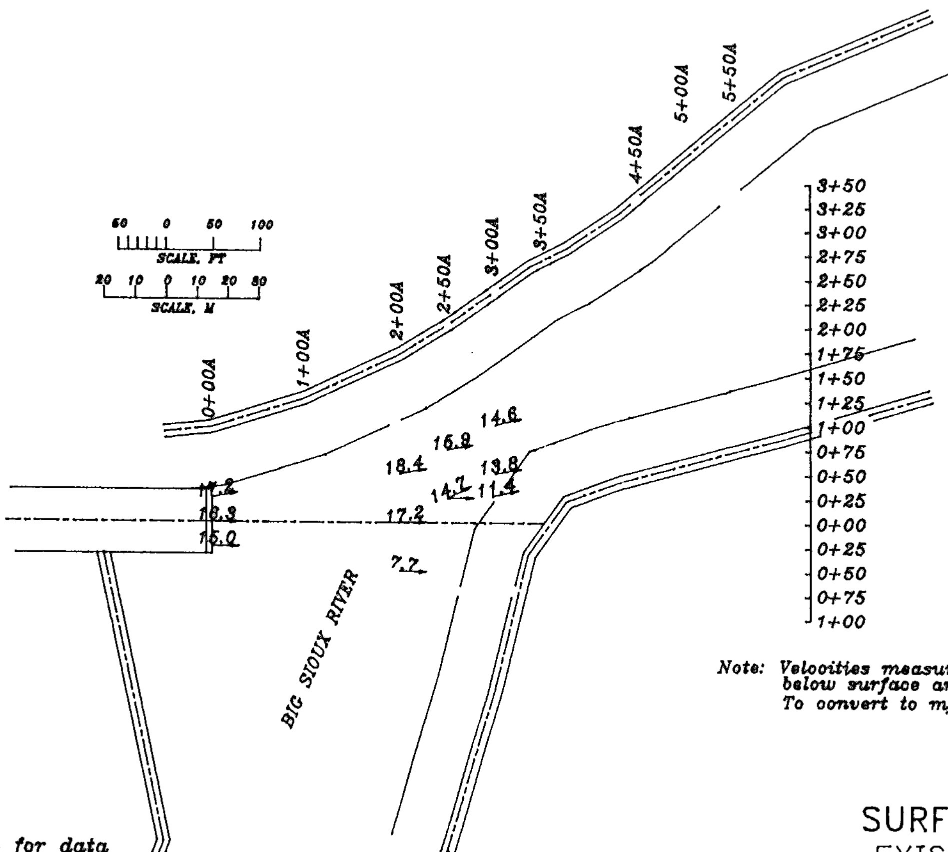
TAILWATER ELEVATION 1326.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 23 for data

BOTTOM VELOCITIES
EXISTING CONDITIONS
Q_C = 700 CU M/SEC (25,000 CFS)
Q_R = 224 CU M/SEC (8,000 CFS)
TAILWATER ELEVATION 1326.0



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 24 for data

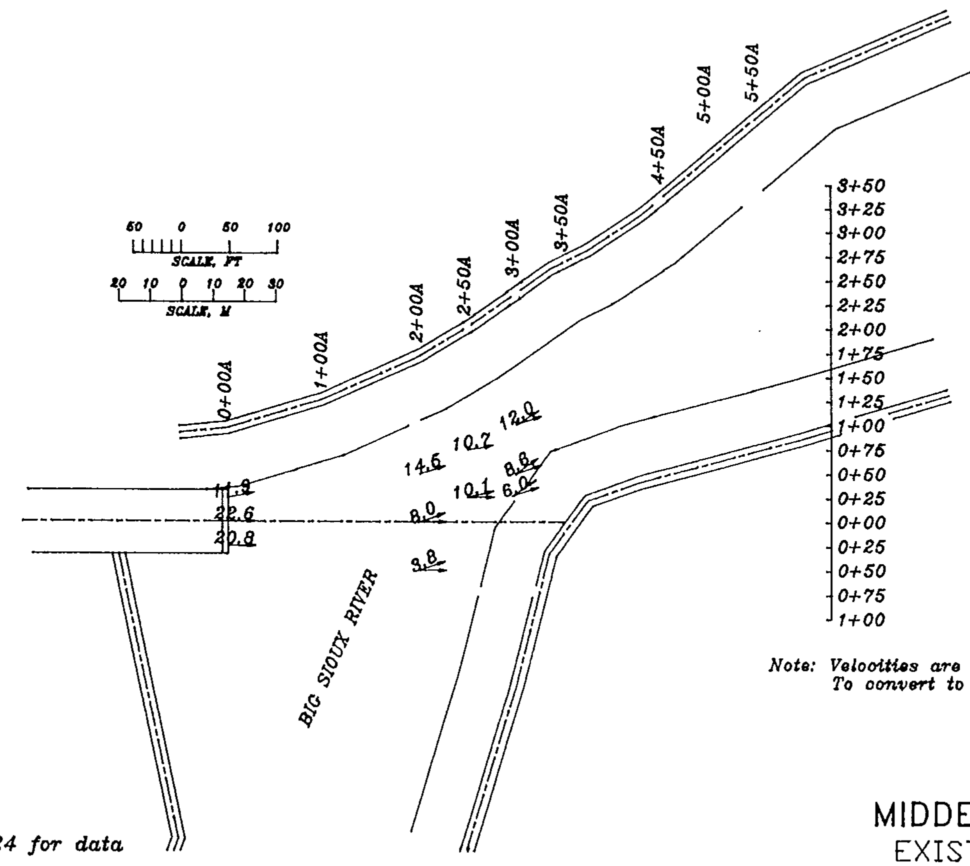
SURFACE VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 204 CU M/SEC (7,300 CFS)

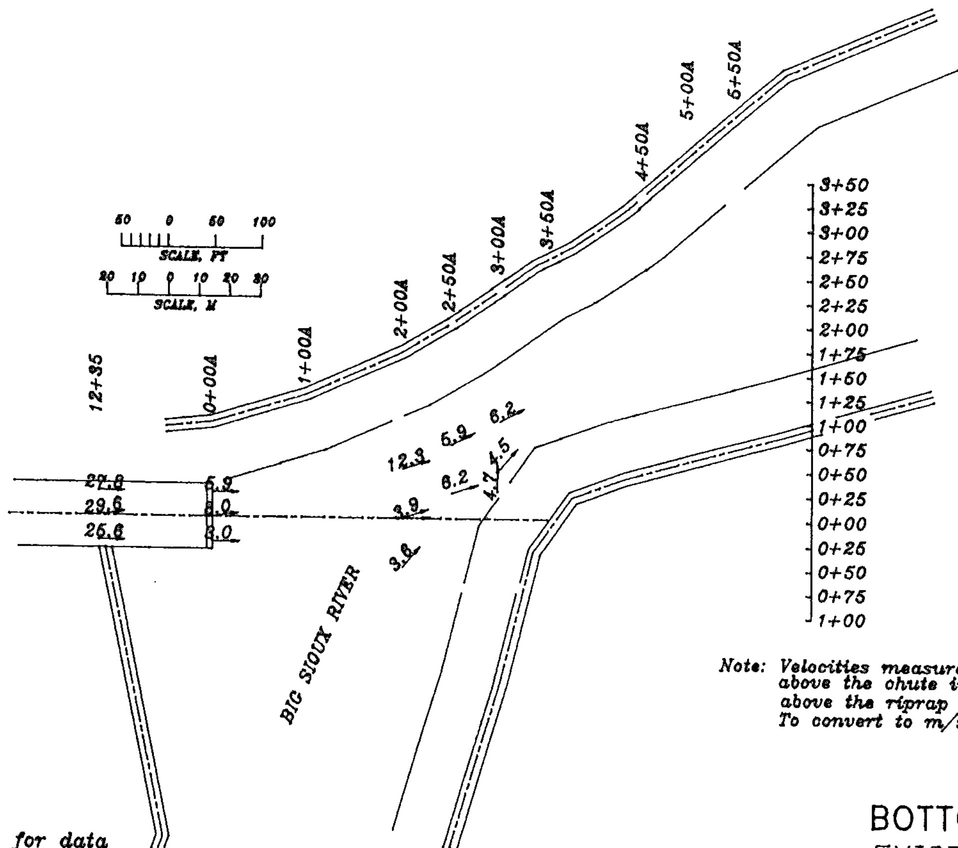
TAILWATER ELEVATION 1322.0



Note: *See Table 24 for data*

Note: *Velocities are given in fps.*
To convert to m/sec multiply by 0.3048.

MIDDEPTH VELOCITIES
EXISTING CONDITIONS
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 204 CU M/SEC (7,300 CFS)
TAILWATER ELEVATION 1322.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 24 for data

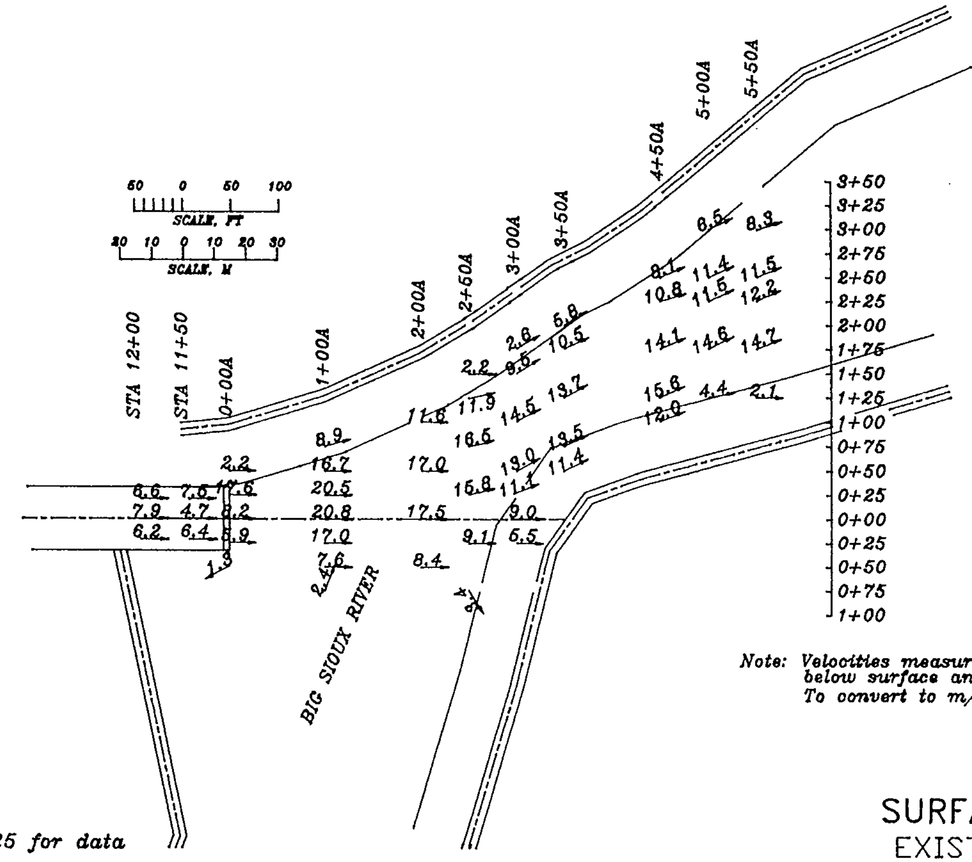
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 204 CU M/SEC (7,300 CFS)

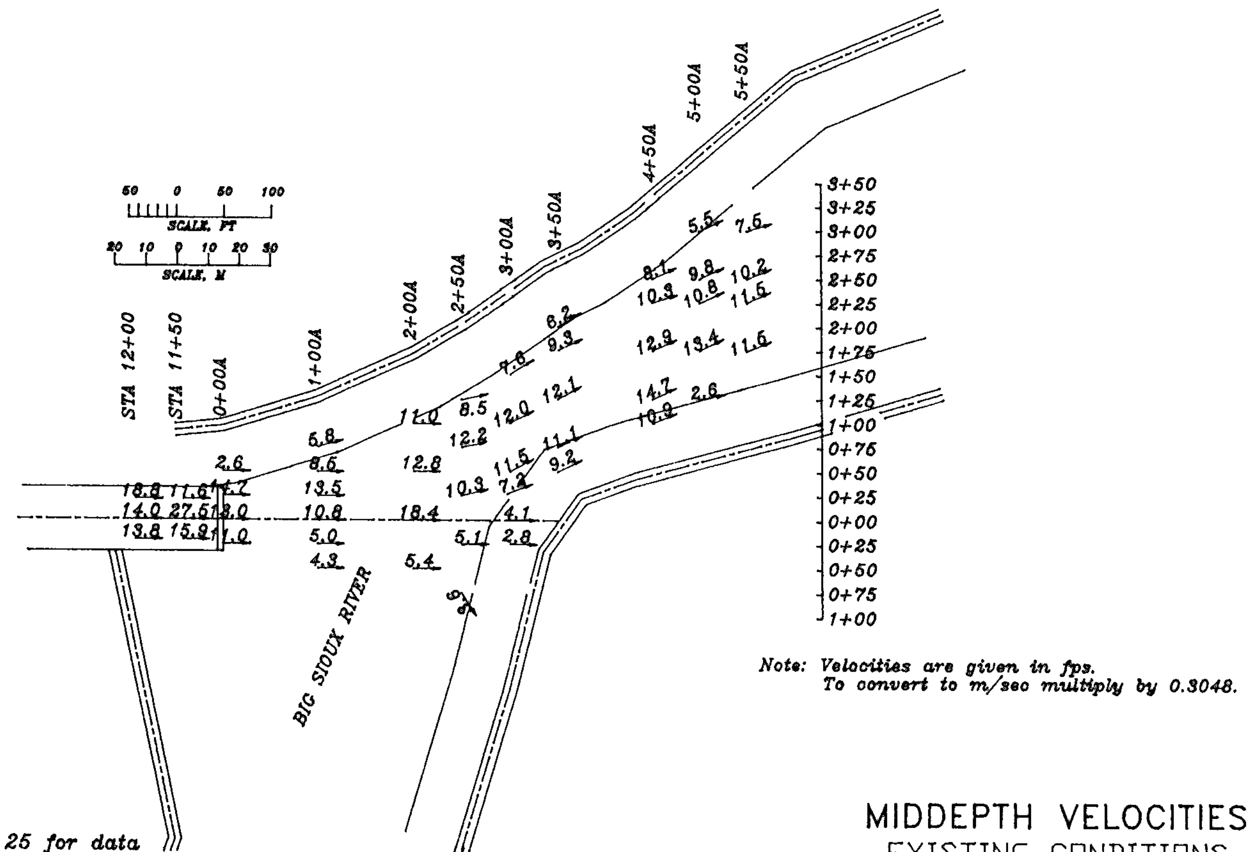
TAILWATER ELEVATION 1322.0



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 25 for data

SURFACE VELOCITIES
EXISTING CONDITIONS
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 204 CU M/SEC (7,300 CFS)
TAILWATER ELEVATION 1322.5



Note: See Table 25 for data

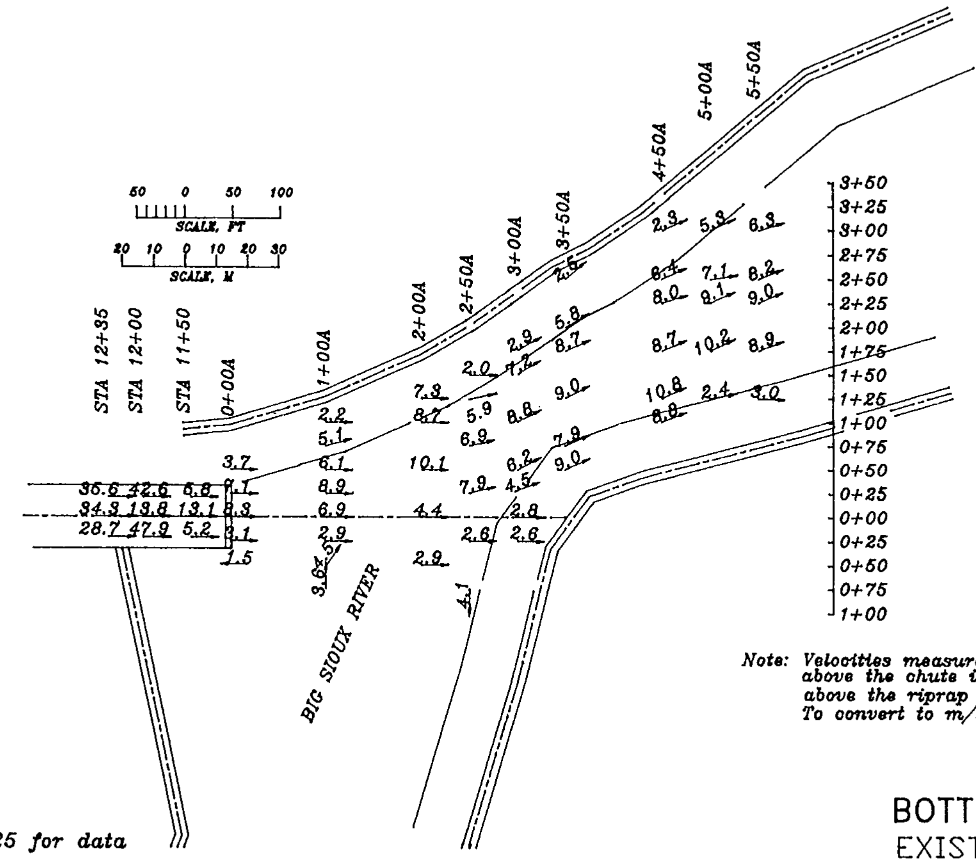
MIDDEPTH VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 204 CU M/SEC (7,300 CFS)

TAILWATER ELEVATION 1322.5



Note: See Table 25 for data

Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

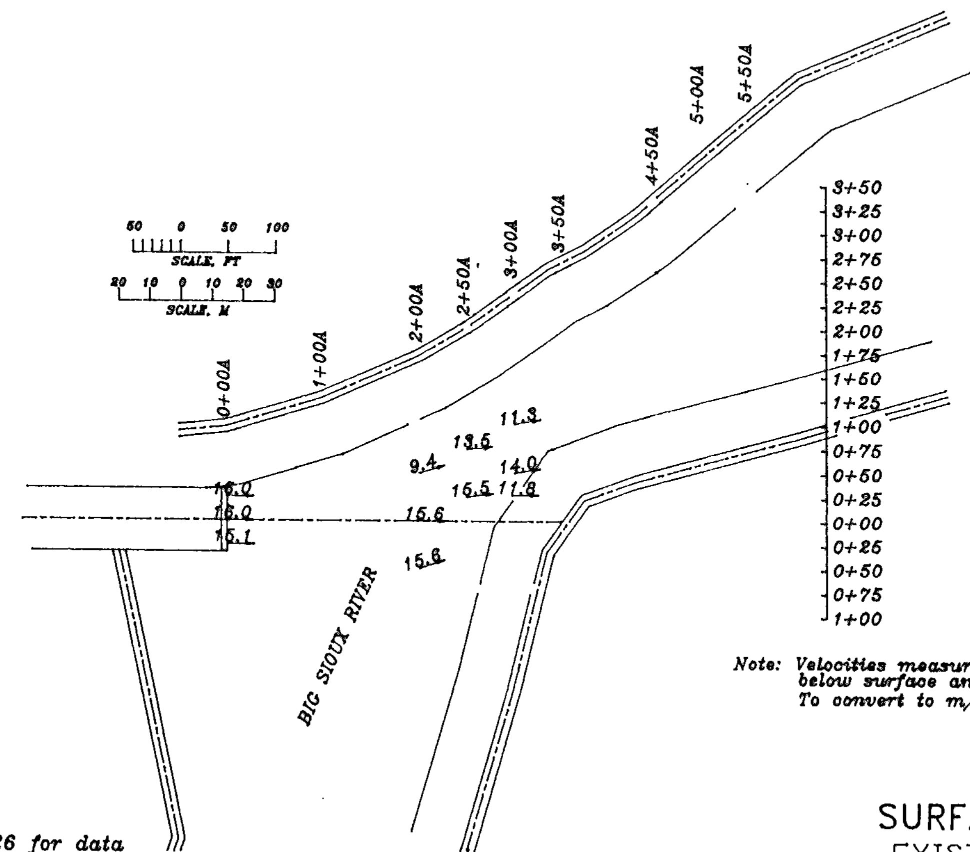
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 204 CU M/SEC (7,300 CFS)

TAILWATER ELEVATION 1322.5



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 26 for data

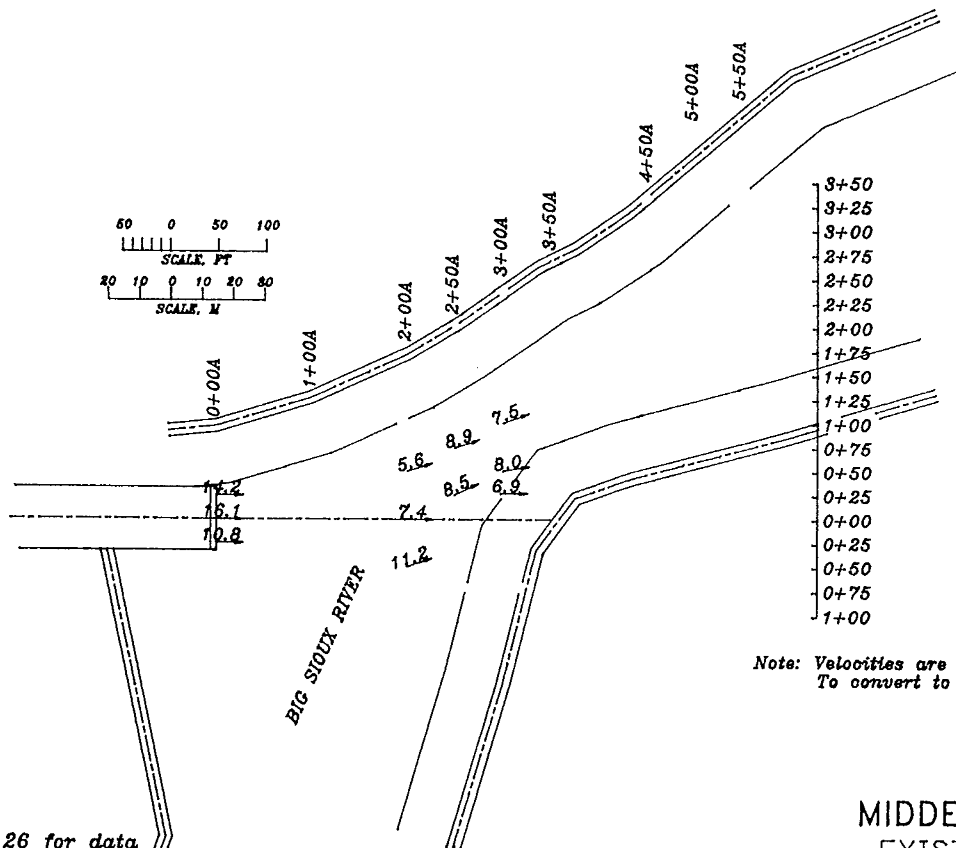
SURFACE VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 204 CU M/SEC (7,300 CFS)

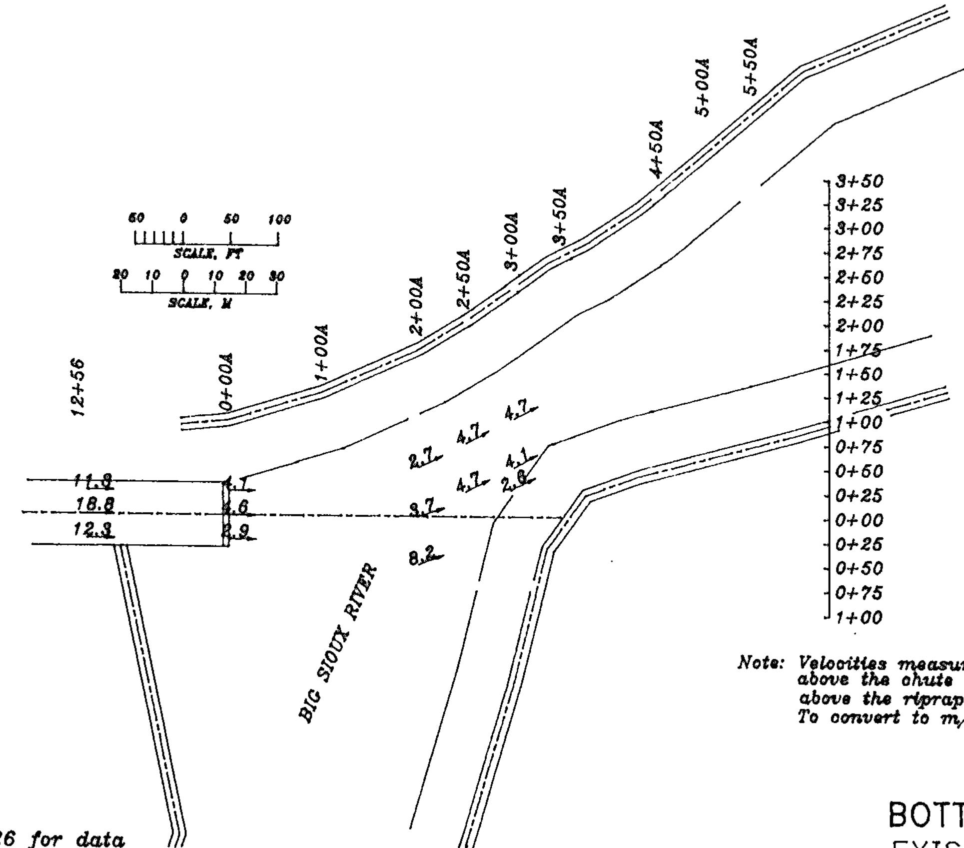
TAILWATER ELEVATION 1328.0



Note: See Table 26 for data

Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

MIDDEPTH VELOCITIES
EXISTING CONDITIONS
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 204 CU M/SEC (7,300 CFS)
TAILWATER ELEVATION 1328.0



Note: See Table 26 for data

Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

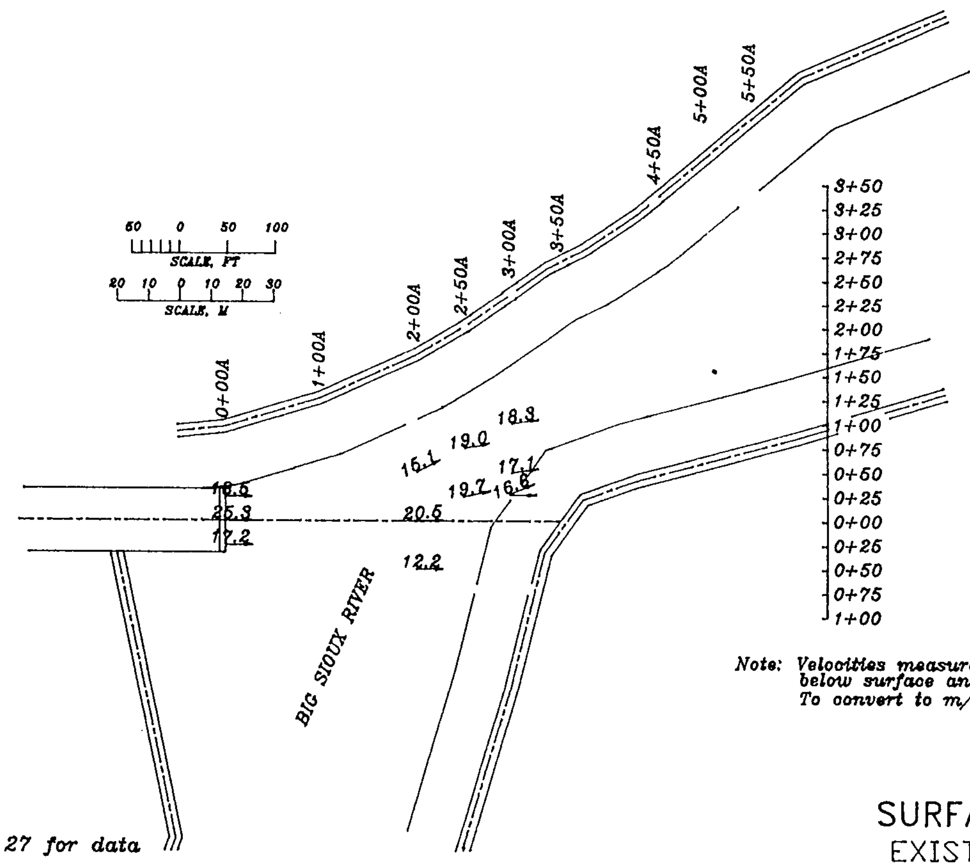
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 204 CU M/SEC (7,300 CFS)

TAILWATER ELEVATION 1328.0



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 27 for data

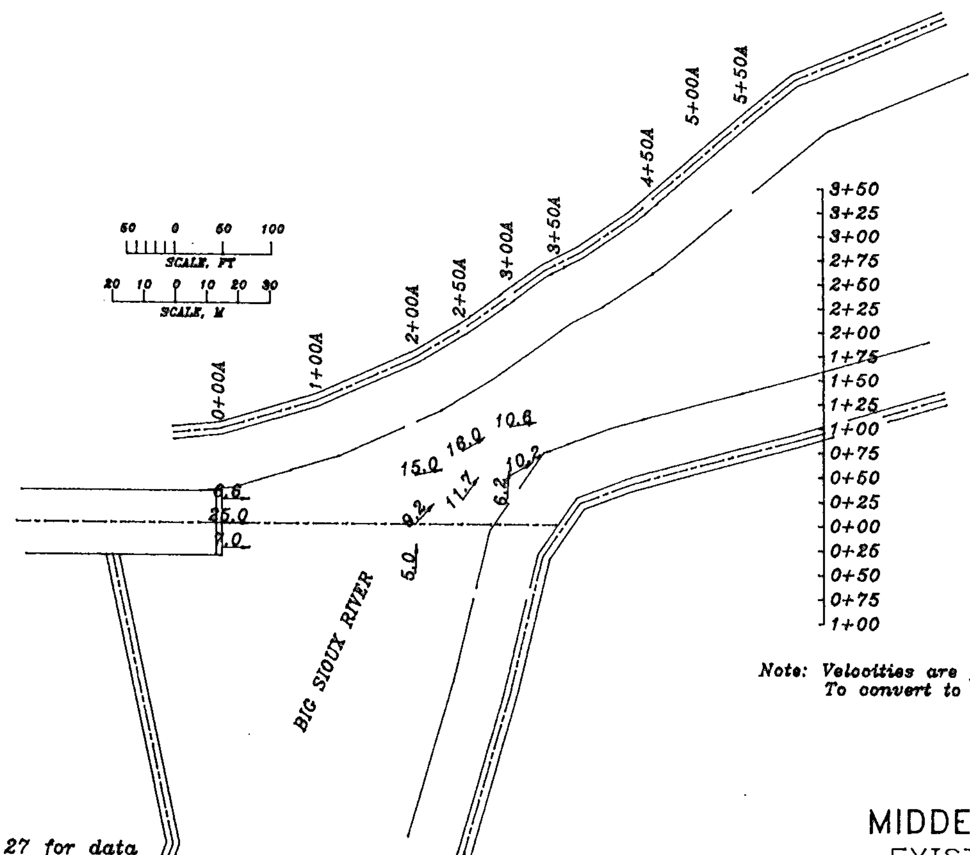
SURFACE VELOCITIES

EXISTING CONDITIONS

Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

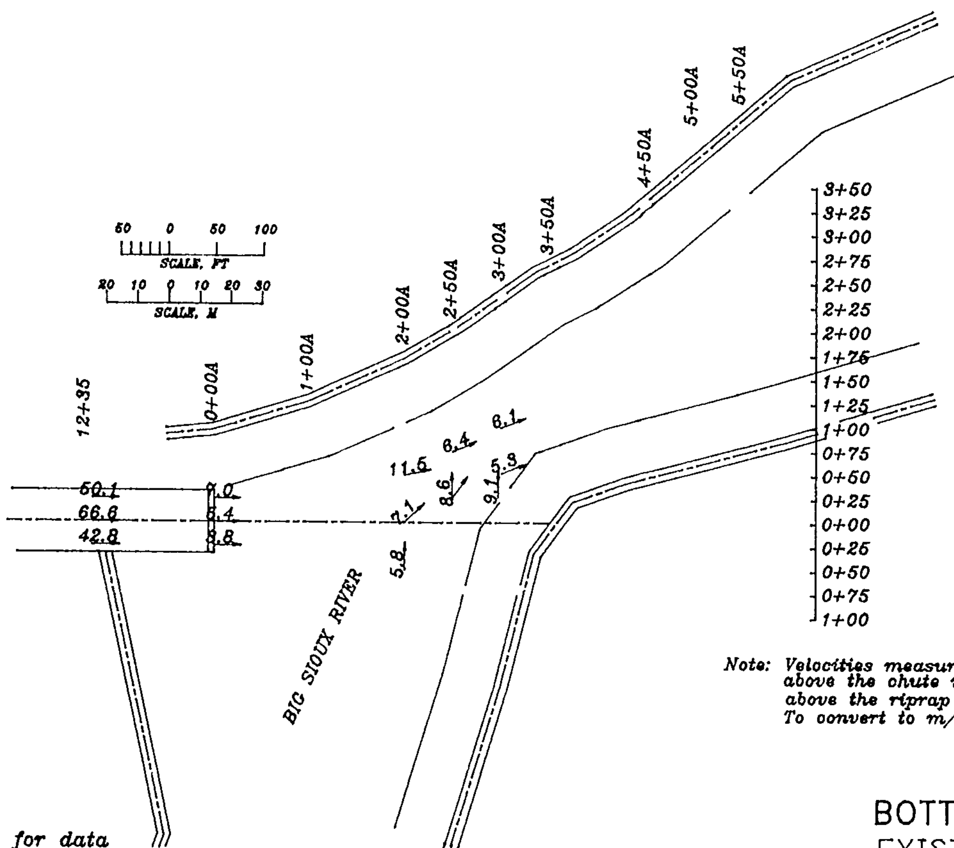
TAILWATER ELEVATION 1326.0



Note: See Table 27 for data

Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

MIDDEPTH VELOCITIES
EXISTING CONDITIONS
Q_C = 1,044 CU M/SEC (37,300 CFS)
Q_R = 812 CU M/SEC (29,000 CFS)
TAILWATER ELEVATION 1326.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 27 for data

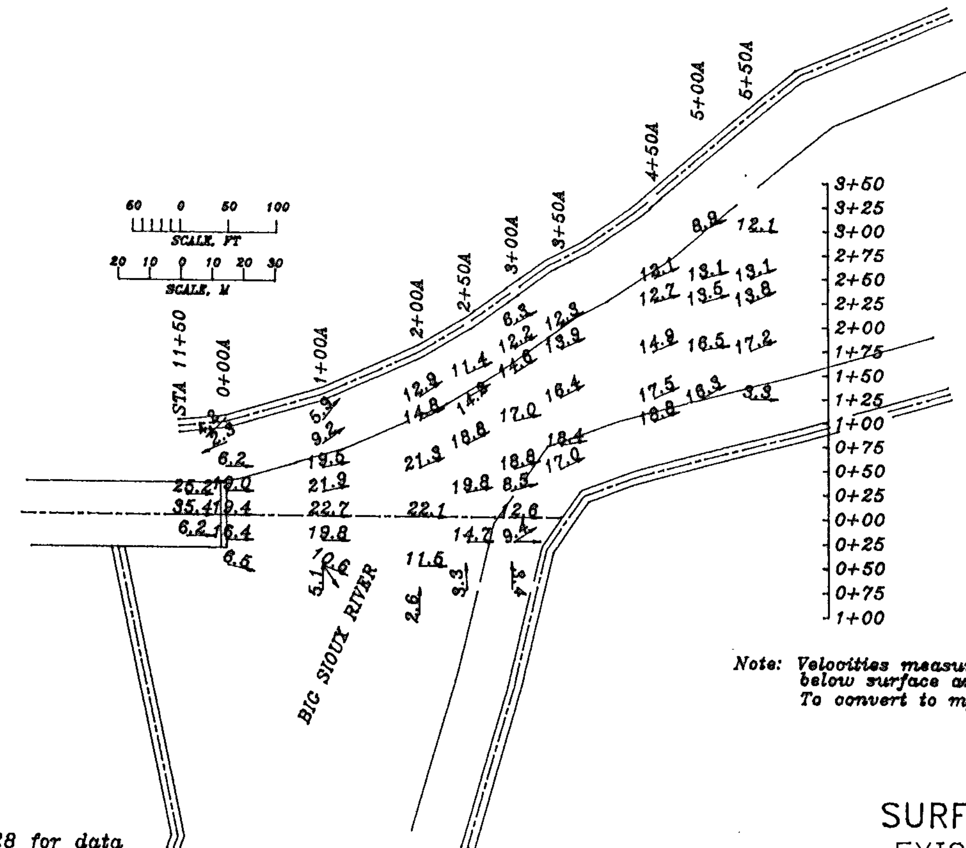
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

TAILWATER ELEVATION 1326.0



Note: See Table 28 for data

Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

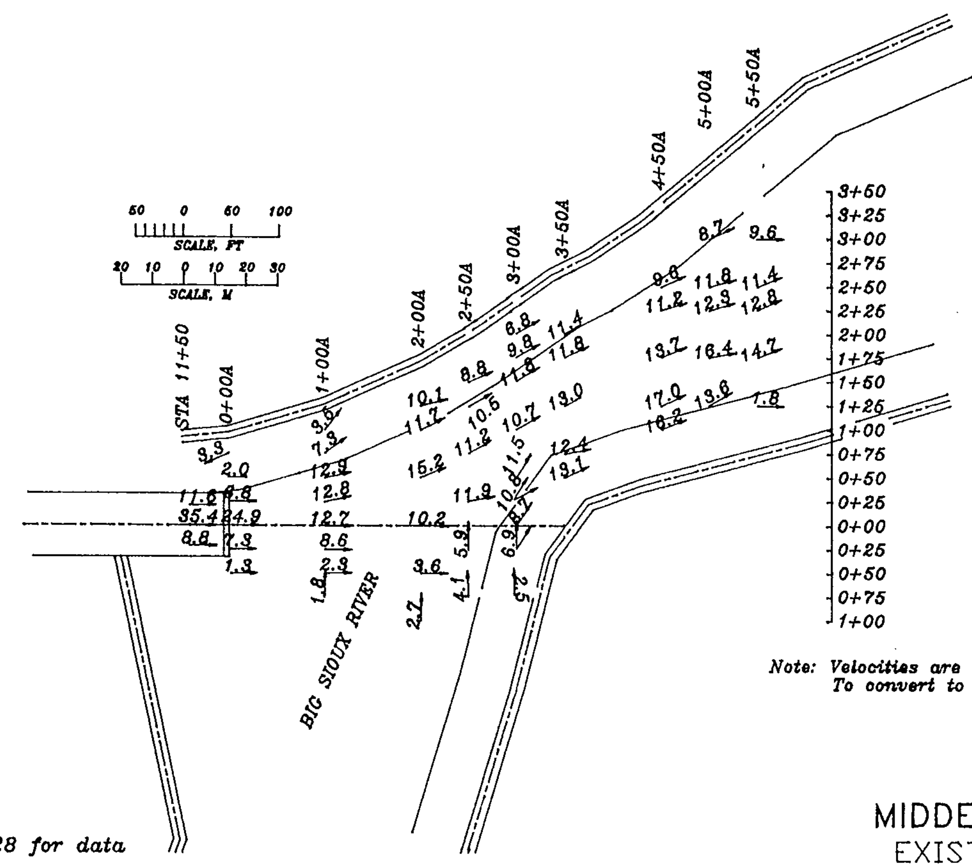
SURFACE VELOCITIES

EXISTING CONDITIONS

Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

TAILWATER ELEVATION 1327.0



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 28 for data

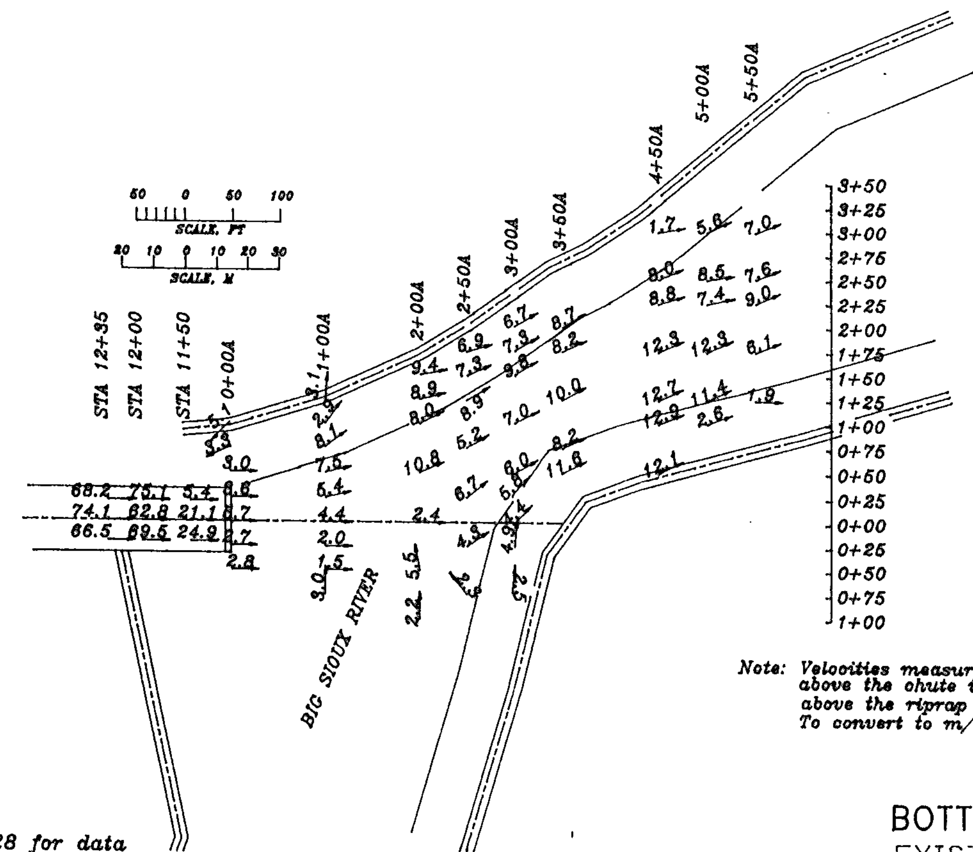
MIDDEPTH VELOCITIES

EXISTING CONDITIONS

Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

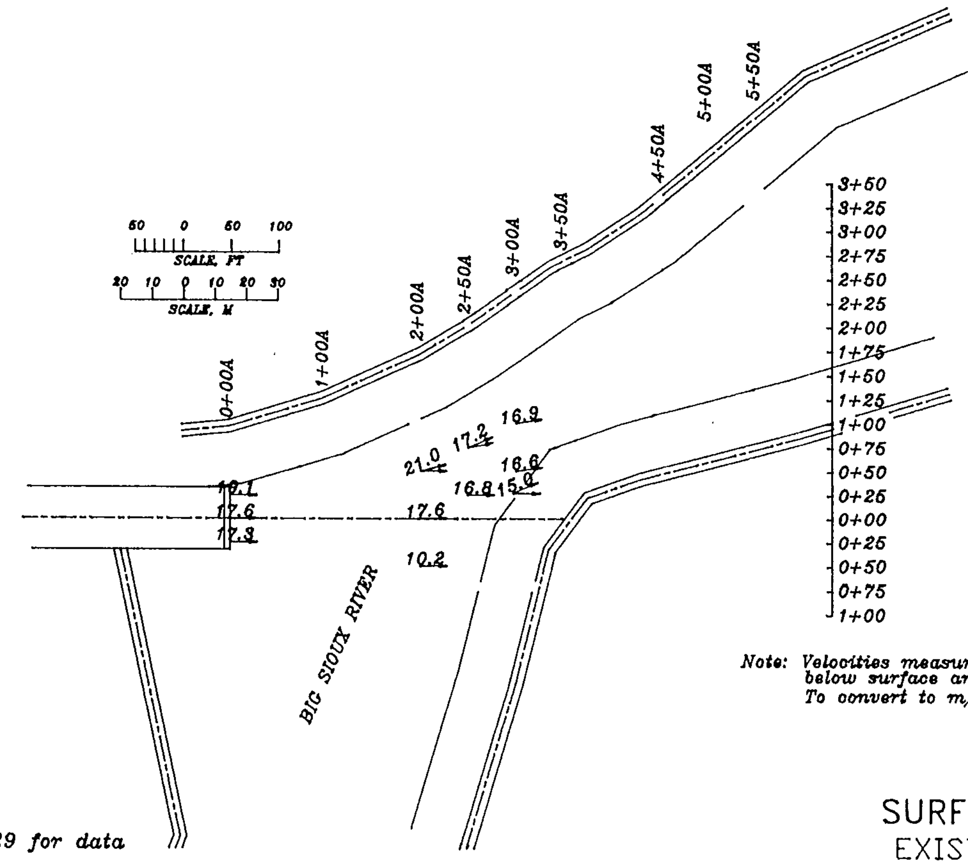
TAILWATER ELEVATION 1327.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 28 for data

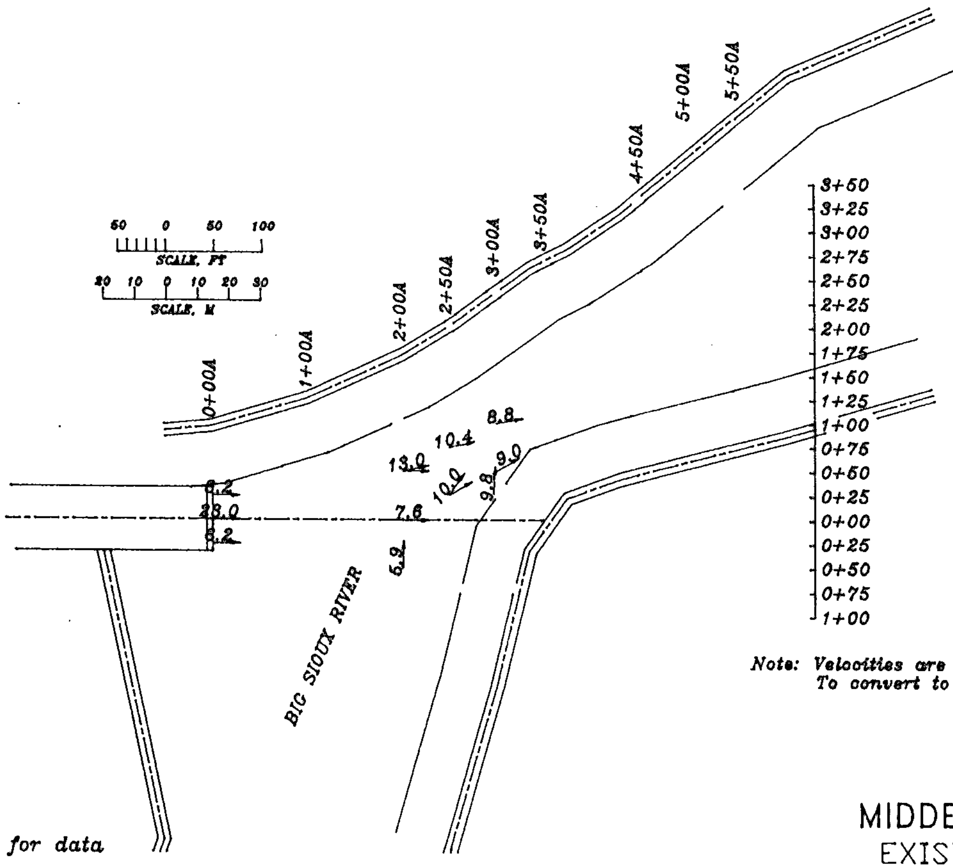
BOTTOM VELOCITIES
EXISTING CONDITIONS
Q_C = 1,044 CU M/SEC (37,300 CFS)
Q_R = 812 CU M/SEC (29,000 CFS)
TAILWATER ELEVATION 1327.0



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 29 for data

SURFACE VELOCITIES
EXISTING CONDITIONS
Q_C = 1,044 CU M/SEC (37,300 CFS)
Q_R = 812 CU M/SEC (29,000 CFS)
TAILWATER ELEVATION 1330.0



Note: *Velocities are given in fps. To convert to m/sec multiply by 0.3048.*

Note: See Table 29 for data

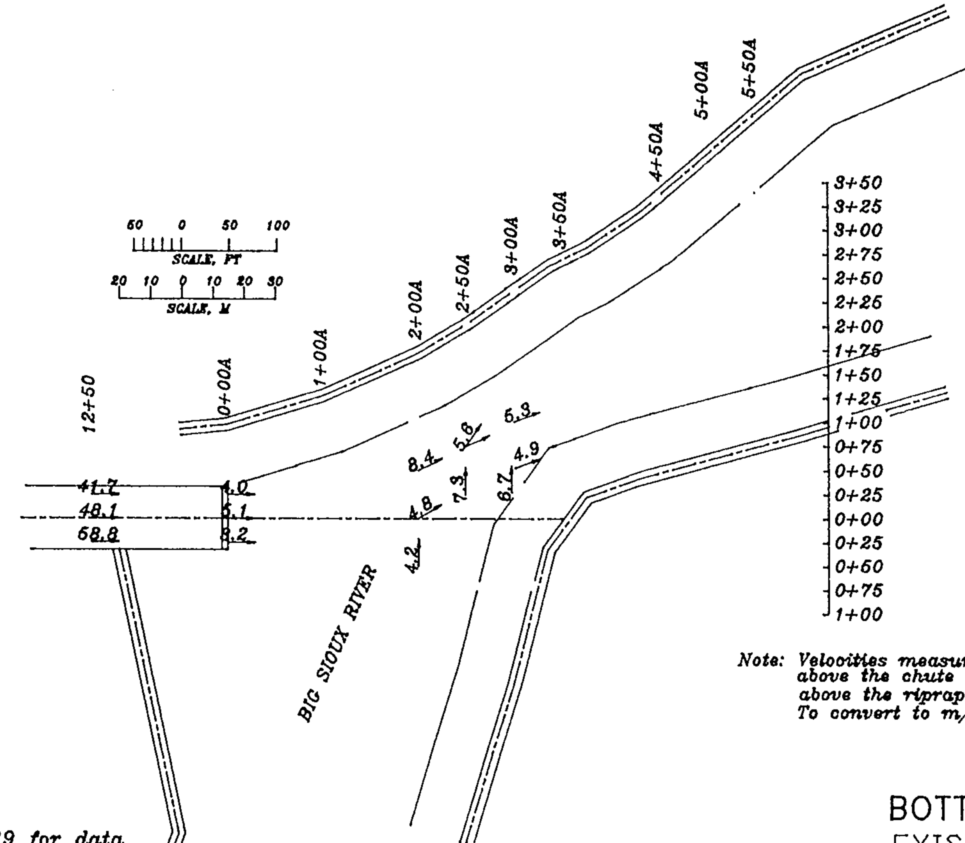
MIDDEPTH VELOCITIES

EXISTING CONDITIONS

Q_C= 1,044 CU M/SEC (37,300 CFS)

Q_R= 812 CU M/SEC (29,000 CFS)

TAILWATER ELEVATION 1330.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 29 for data

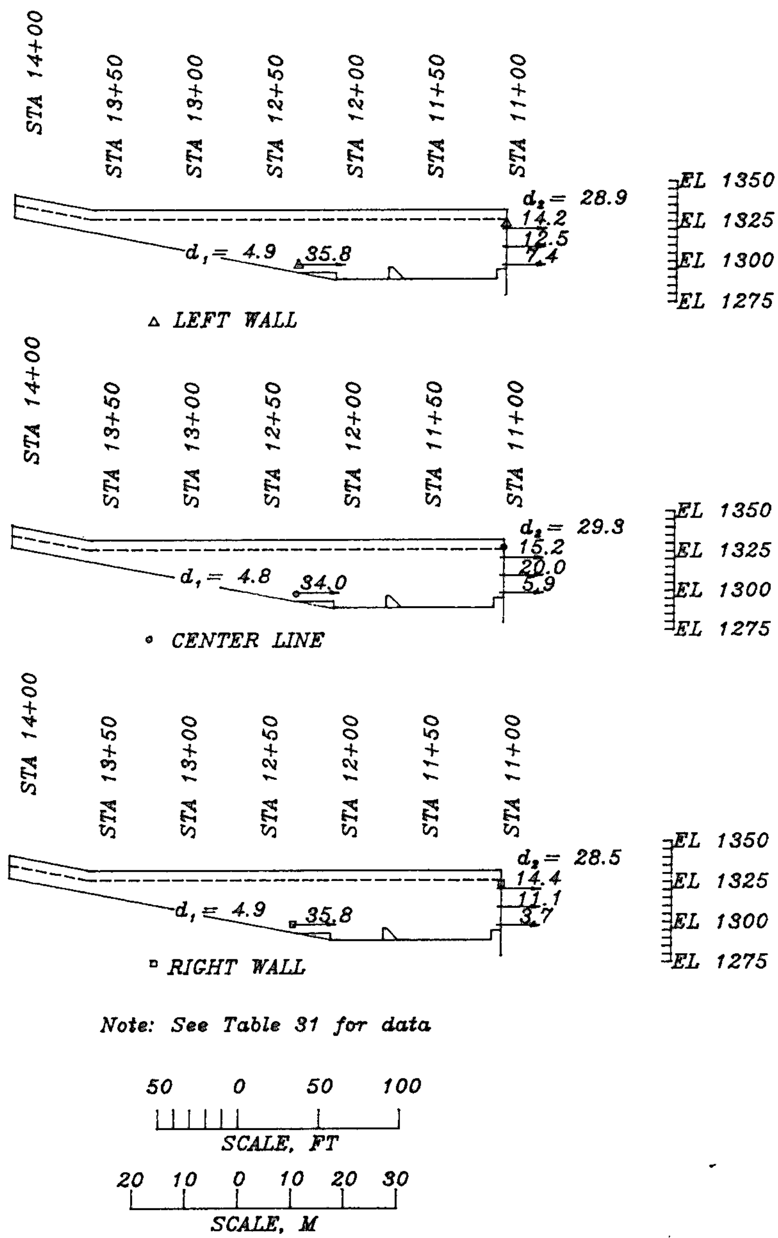
BOTTOM VELOCITIES

EXISTING CONDITIONS

Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

TAILWATER ELEVATION 1330.0

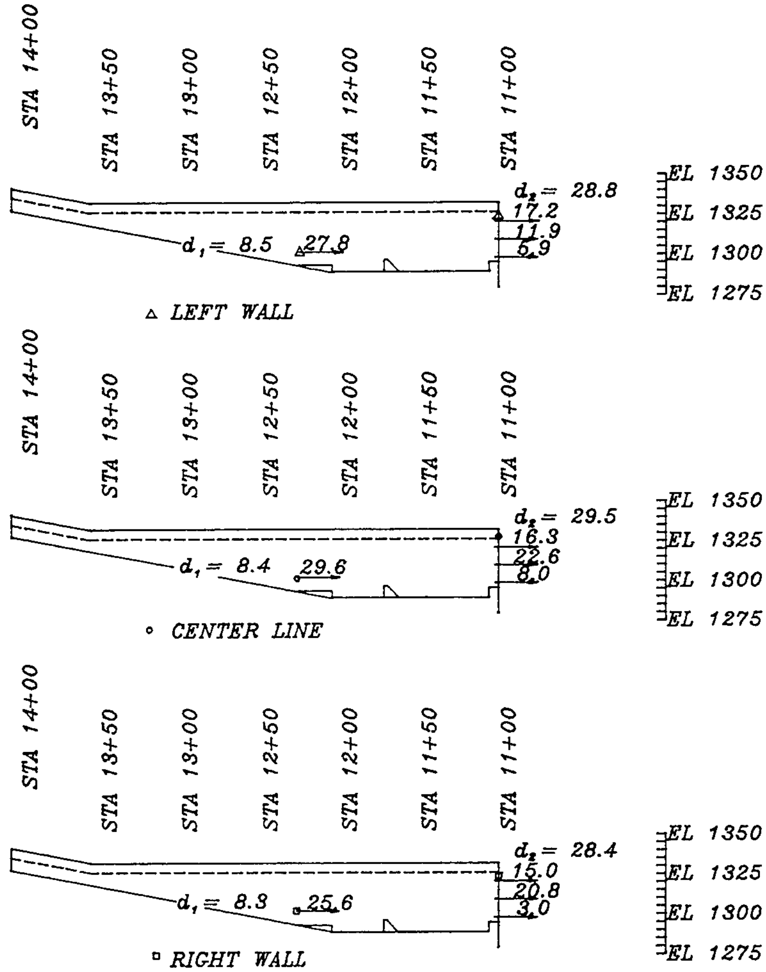


Note: Dimensions given in feet.
To convert to m, multiply by 0.3048.
Velocities measured 0.3 m (1 ft) below surface and above end sill and are given in fps. To convert
To convert to m/sec multiply by 0.3048.

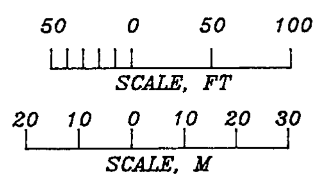
D_1, V_1, D_2, V_2

EXISTING CHANNEL CONFIGURATION
TYPE 1 BASIN

Q_C = 700 CU M/SEC (25,000 CFS)
Q_R = 224 CU M/SEC (8,000 CFS)
TAILWATER ELEVATION 1320.0



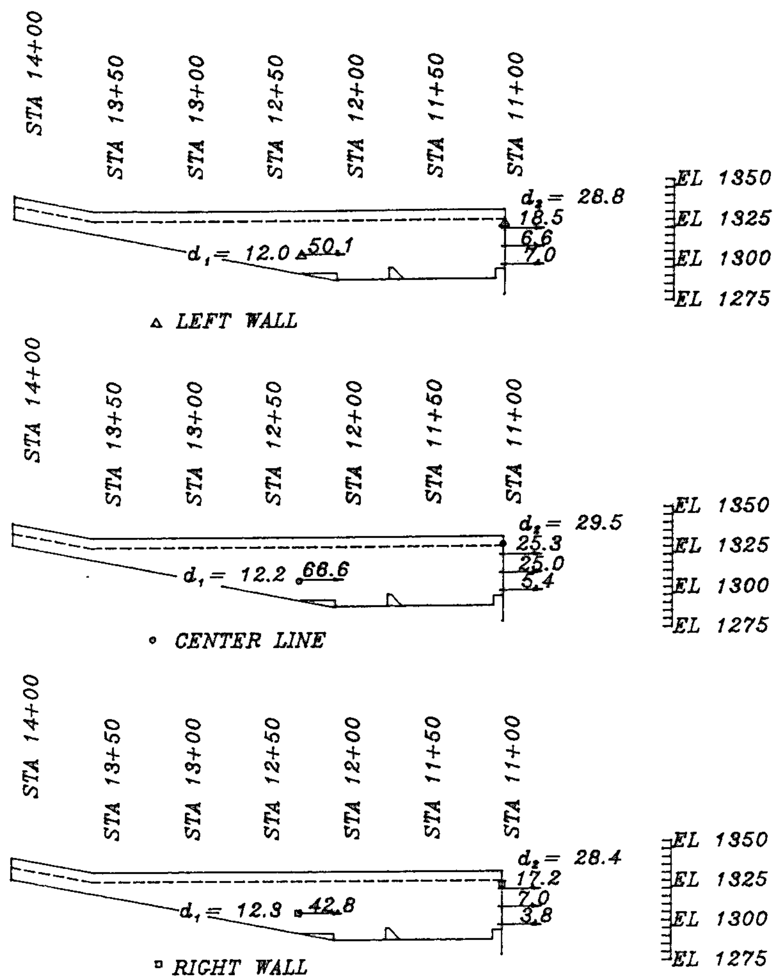
Note: See Table 31 for data



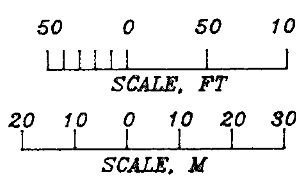
*Note: Dimensions given in feet.
To convert to m, multiply by 0.3048.
Velocities measured 0.3 m (1 ft)
below surface and above end sill
and are given in fps. To convert
To convert to m/sec multiply by 0.3048.*

D_1, V_1, D_2, V_2

EXISTING CHANNEL CONFIGURATION
TYPE 1 BASIN
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 204 CU M/SEC (7,300 CFS)
TAILWATER ELEVATION 1322.0

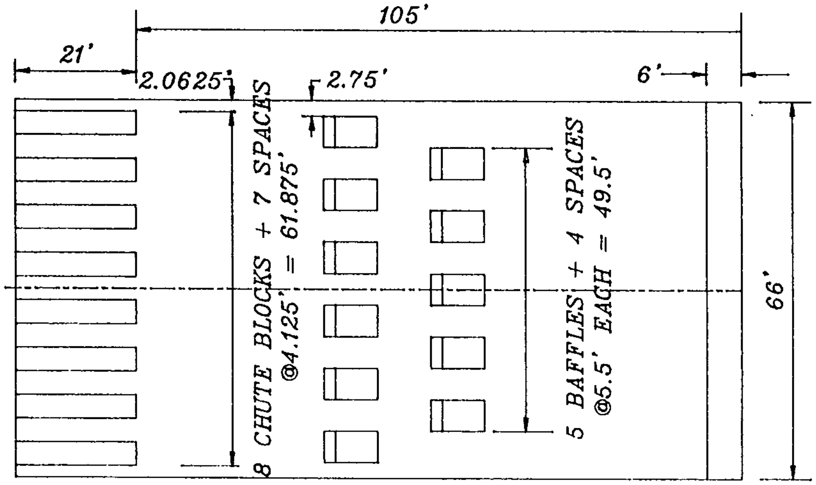


Note: See Table 31 for data

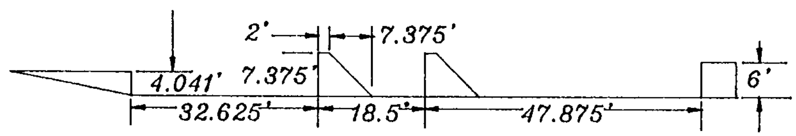


Note: Dimensions given in feet.
To convert to m, multiply by 0.3048.
Velocities measured 0.3 m (1 ft)
below surface and above end sill
and are given in fps. To convert
To convert to m/sec multiply by 0.3048.

D_1, V_1, D_2, V_2
EXISTING CHANNEL CONFIGURATION
TYPE 1 BASIN
Q_C = 1,044 CU M/SEC (37,300 CFS)
Q_R = 812 CU M/SEC (29,000 CFS)
TAILWATER ELEVATION 1326.0



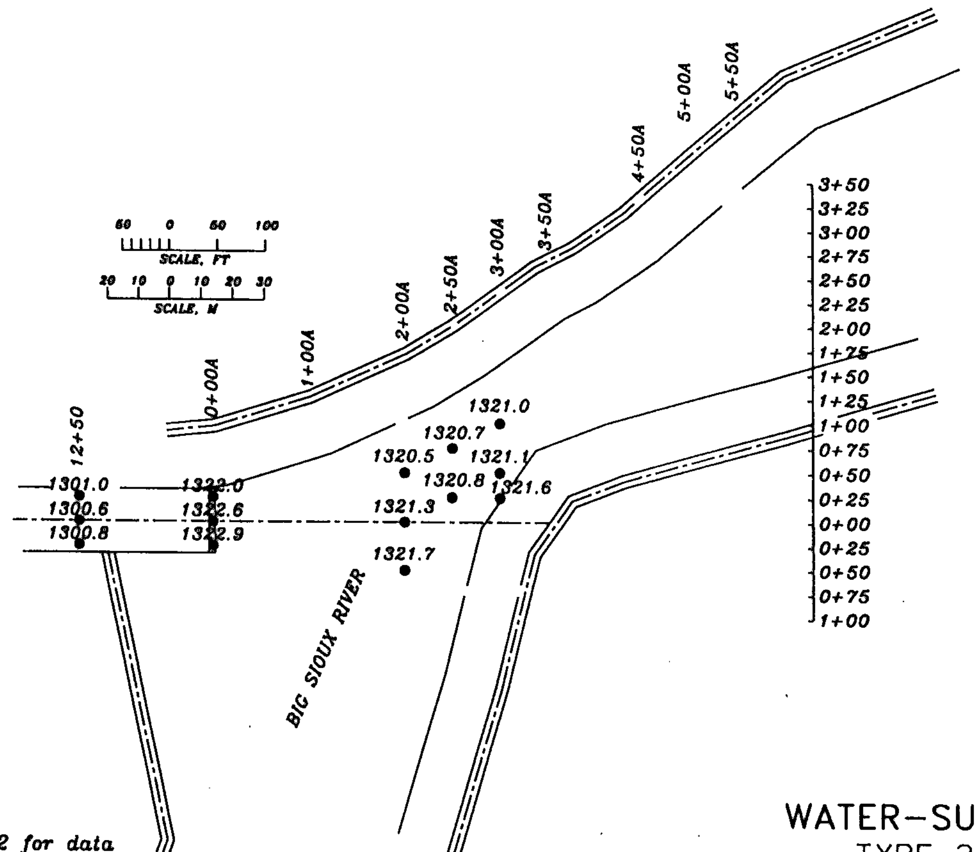
PLAN VIEW



PROFILE VIEW

Note: To convert dimensions to meters, multiply by 0.3048.

TYPE 2
STILLING BASIN



Note: See Table 32 for data

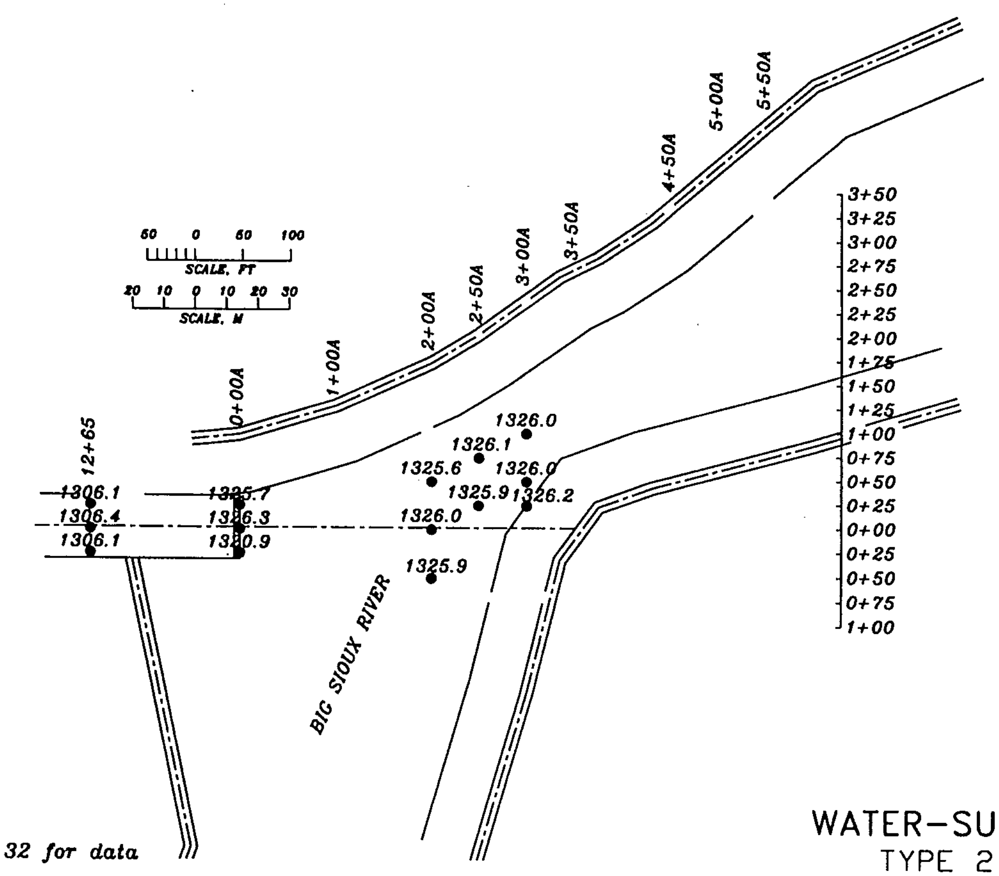
WATER–SURFACE ELEVATIONS

TYPE 2 STILLING BASIN

Q_C = 700 CU M/SEC (25,000 CFS)

Q_R = 224 CU M/SEC (8,000 CFS)

TAILWATER ELEVATION 1320.0



Note: See Table 32 for data

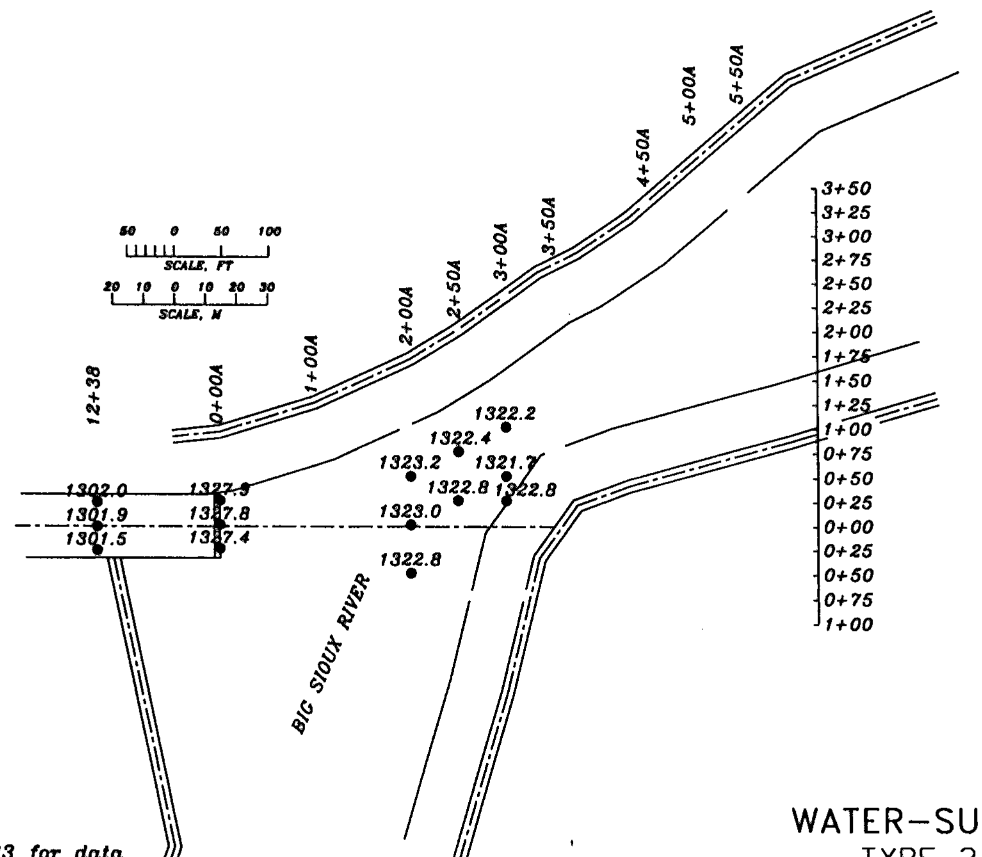
WATER–SURFACE ELEVATIONS

TYPE 2 STILLING BASIN

Q_C = 700 CU M/SEC (25,000 CFS)

Q_R = 224 CU M/SEC (8,000 CFS)

TAILWATER ELEVATION 1326.0



Note: See Table 33 for data

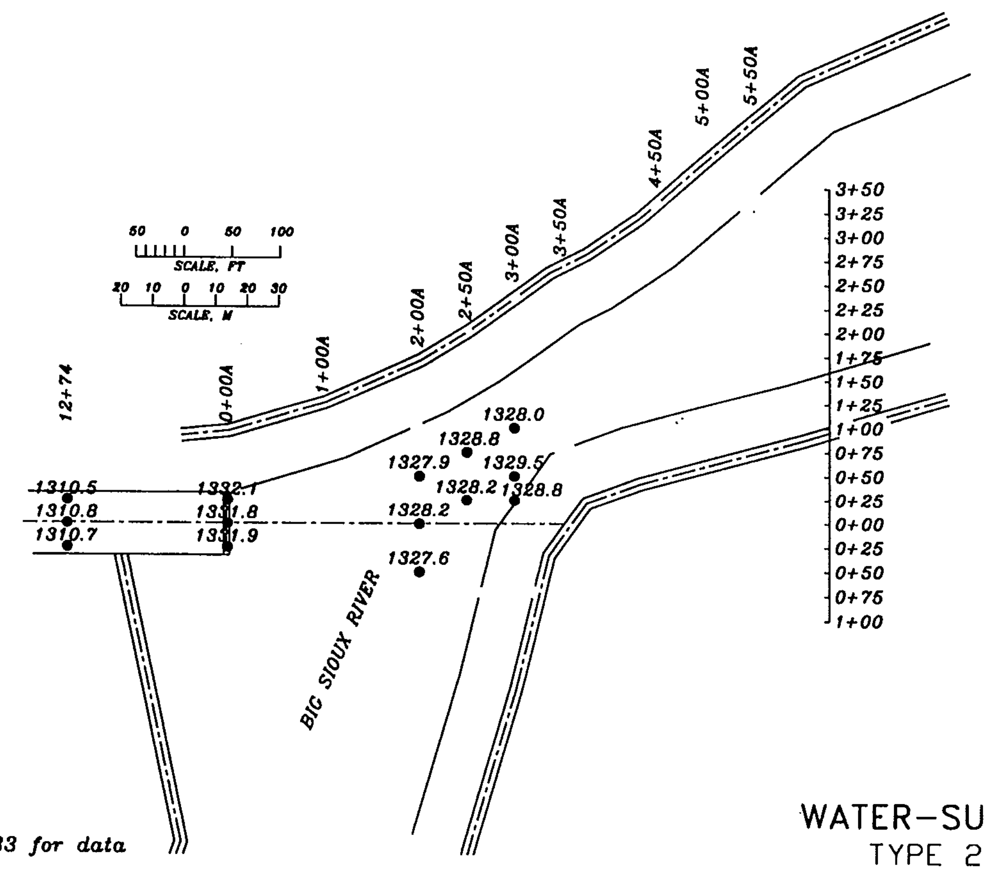
WATER–SURFACE ELEVATIONS

TYPE 2 STILLING BASIN

Q_C = 812 CU M/SEC (29,000 CFS)

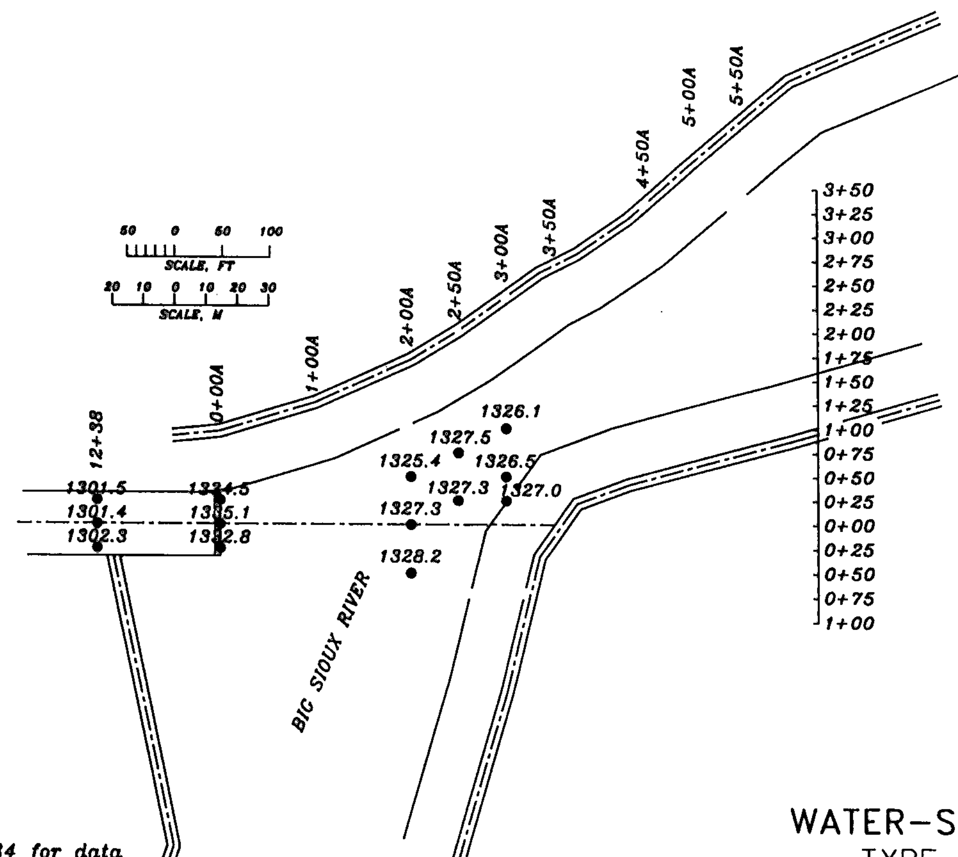
Q_R = 204 CU M/SEC (7,300 CFS)

TAILWATER ELEVATION 1322.0



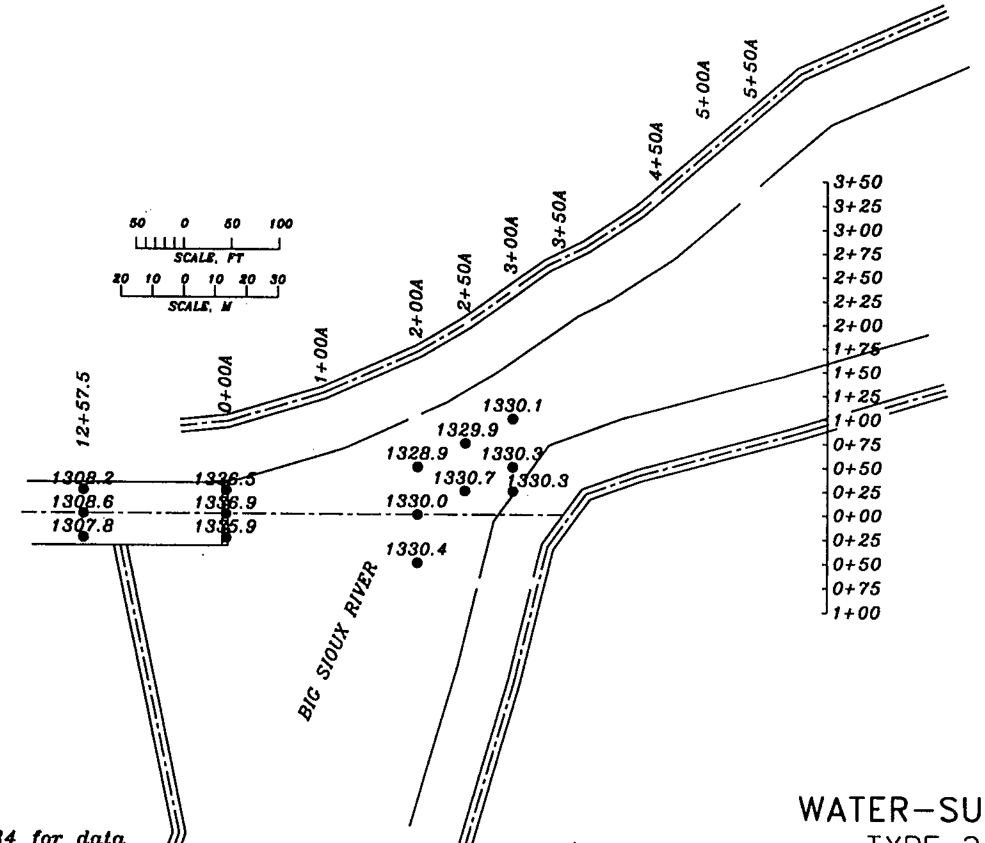
Note: See Table 33 for data

WATER–SURFACE ELEVATIONS
TYPE 2 STILLING BASIN
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 204 CU M/SEC (7,300 CFS)
TAILWATER ELEVATION 1328.0



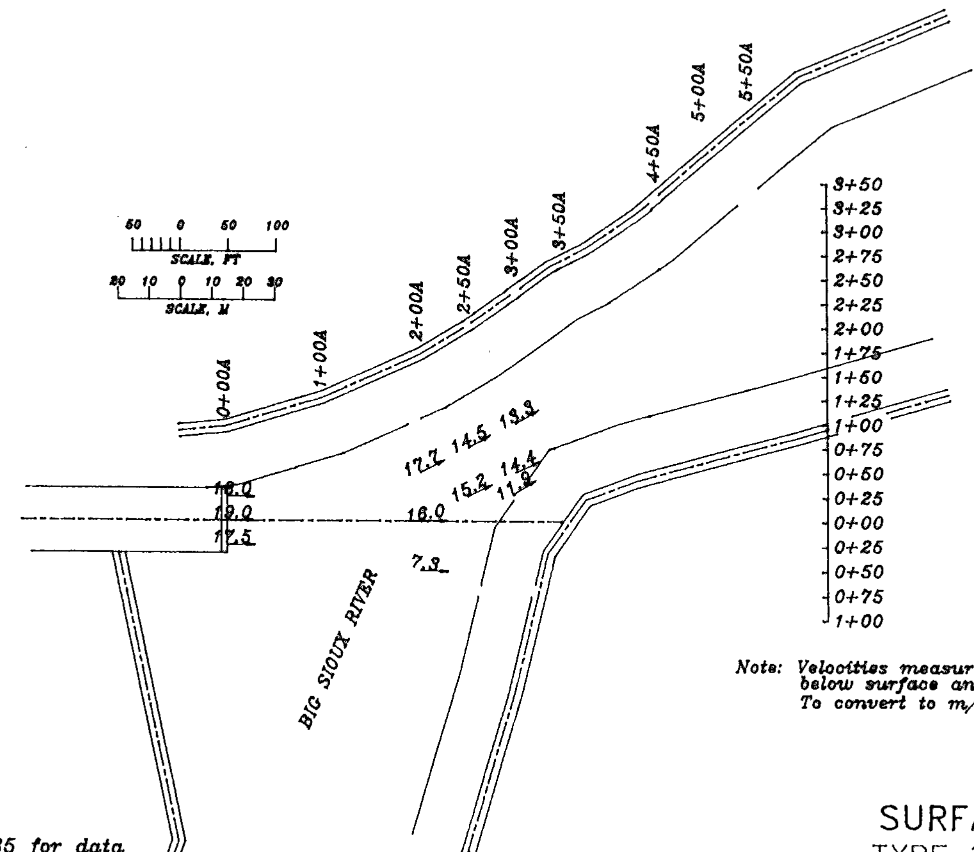
Note: See Table 34 for data

WATER-SURFACE ELEVATIONS
TYPE 2 STILLING BASIN
Q_C = 1,044 CU M/SEC (37,300 CFS)
Q_R= 812 CU M/SEC (29,000 CFS)
TAILWATER ELEVATION 1326.0



Note: See Table 34 for data

WATER–SURFACE ELEVATIONS
TYPE 2 STILLING BASIN
Q_C = 1,044 CU M/SEC (37,300 CFS)
Q_R = 812 CU M/SEC (29,000 CFS)
TAILWATER ELEVATION 1330.0



Note: See Table 35 for data

Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

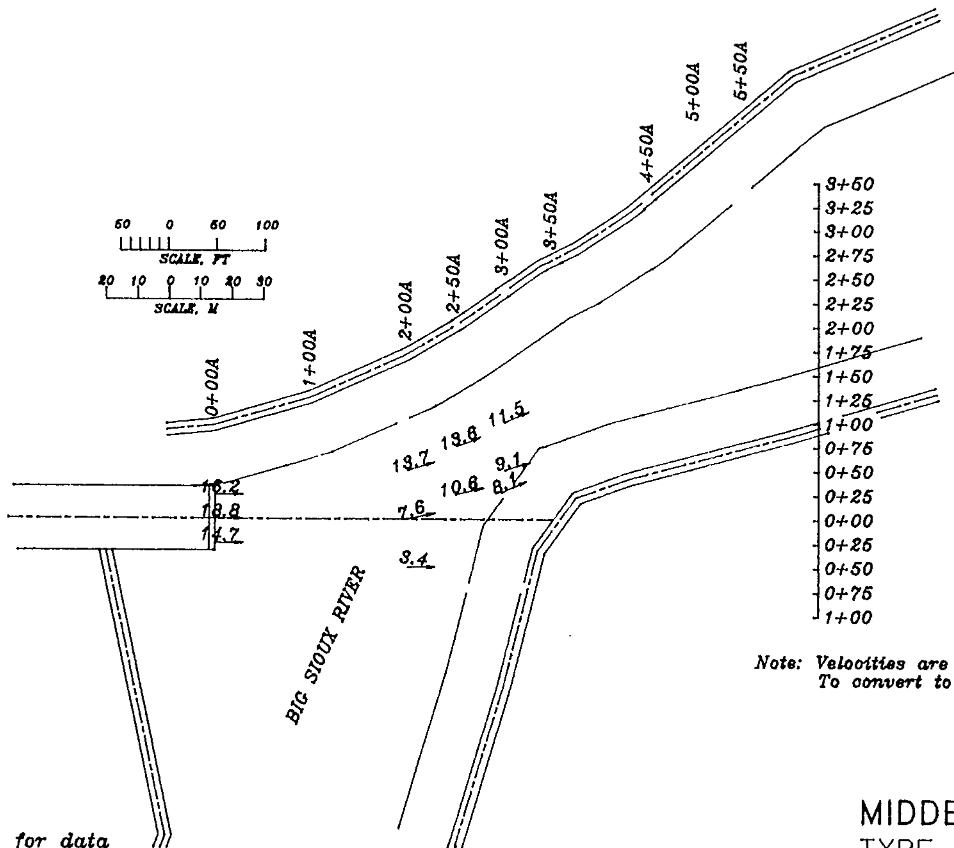
SURFACE VELOCITIES

TYPE 2 STILLING BASIN

Q_C = 700 CU M/SEC (25,000 CFS)

Q_R = 224 CU M/SEC (8,000 CFS)

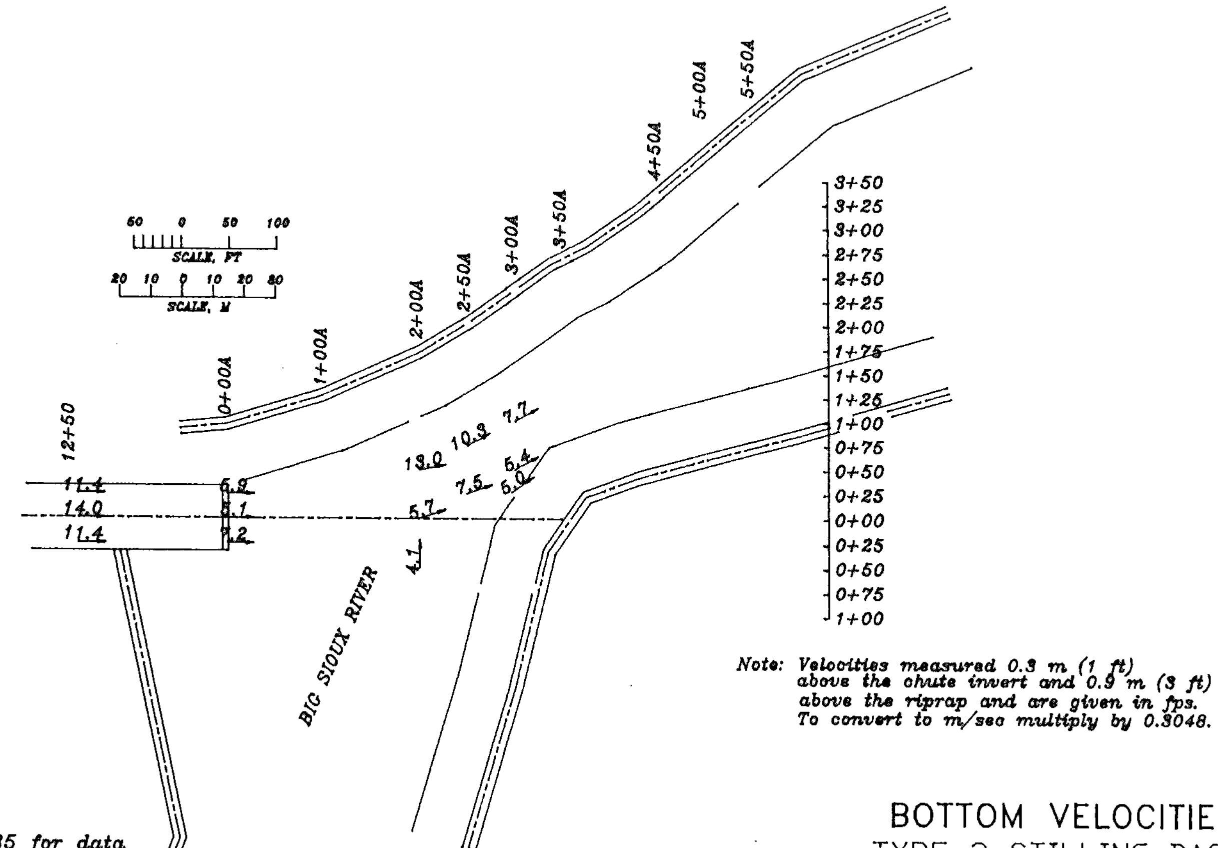
TAILWATER ELEVATION 1320.0



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 35 for data

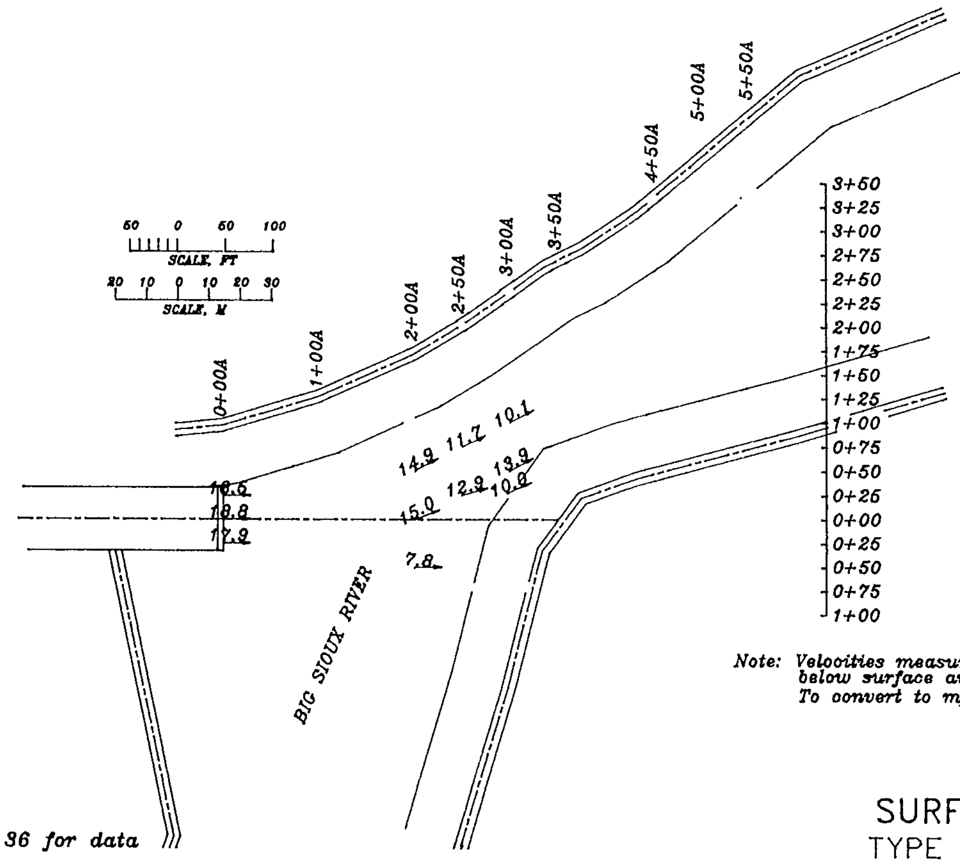
MIDDEPTH VELOCITIES
TYPE 2 STILLING BASIN
Q_C = 700 CU M/SEC (25,000 CFS)
Q_R =224 CU M/SEC (8,000 CFS)
TAILWATER ELEVATION 1320.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 35 for data

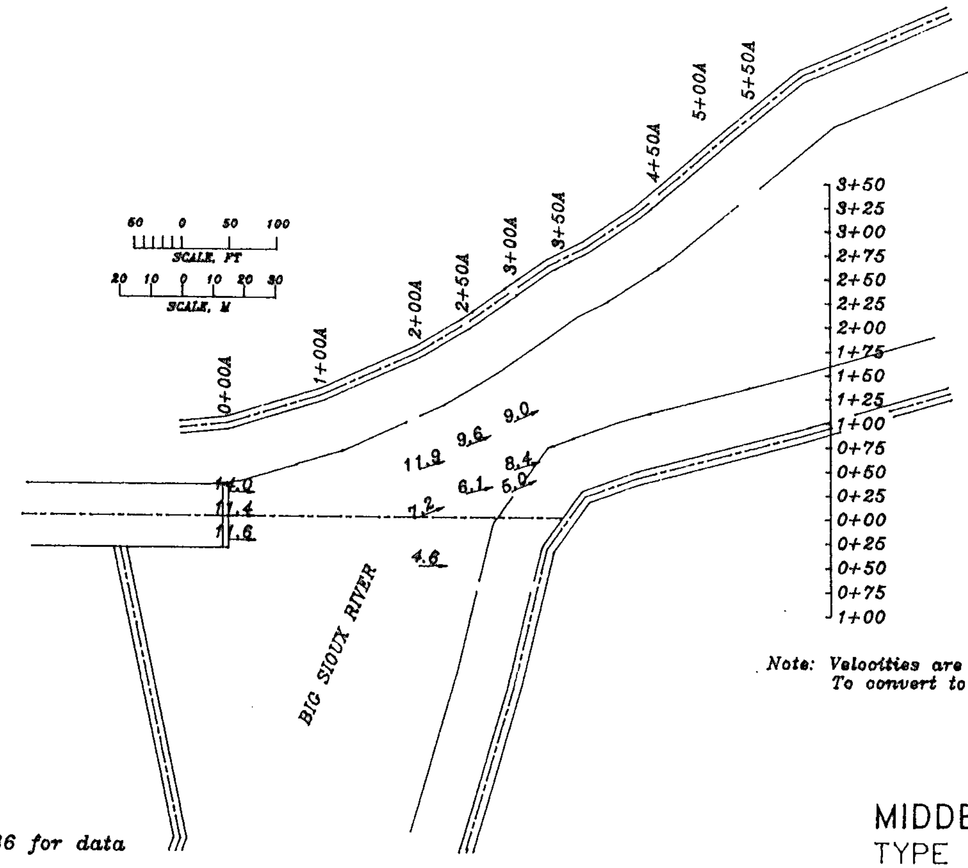
BOTTOM VELOCITIES
TYPE 2 STILLING BASIN
Q_C = 700 CU M/SEC (25,000 CFS)
Q_R = 224 CU M/SEC (8,000 CFS)
TAILWATER ELEVATION 1320.0



Note: See Table 36 for data

Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

SURFACE VELOCITIES
TYPE 2 STILLING BASIN
Q_C = 700 CU M/SEC (25,000 CFS)
Q_R = 224 CU M/SEC (8,000 CFS)
TAILWATER ELEVATION 1326.0



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 36 for data

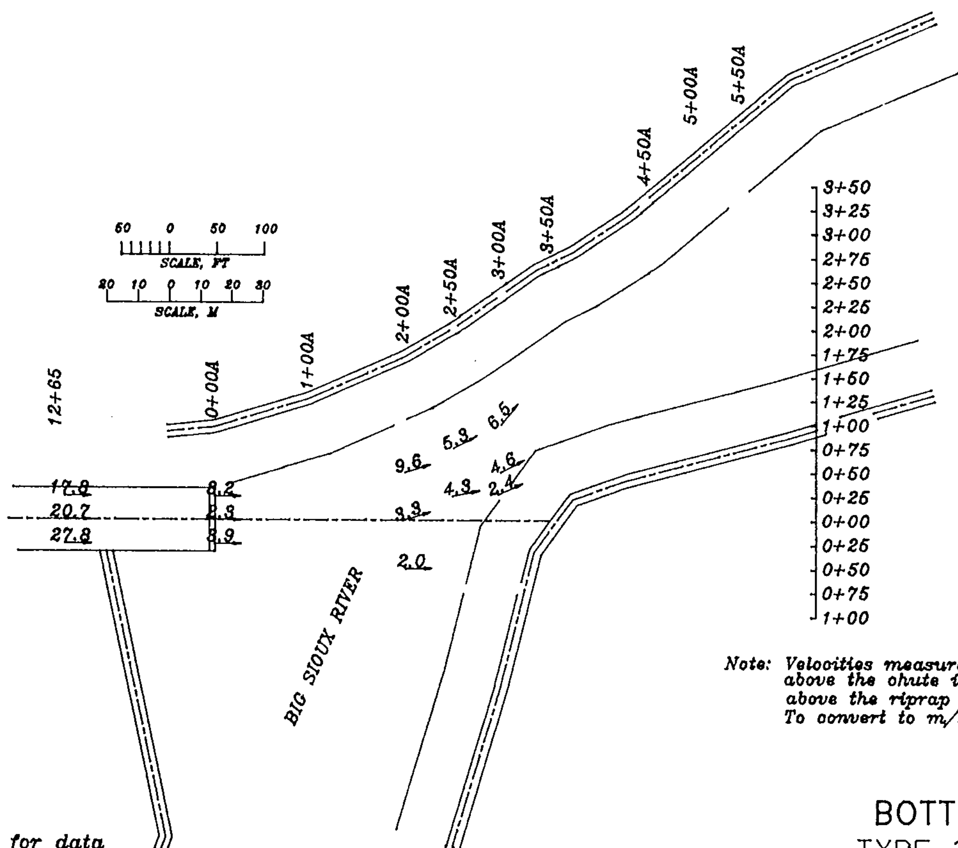
MIDDEPTH VELOCITIES

TYPE 2 STILLING BASIN

Q_C = 700 CU M/SEC (25,000 CFS)

Q_R =224 CU M/SEC (8,000 CFS)

TAILWATER ELEVATION 1326.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 36 for data

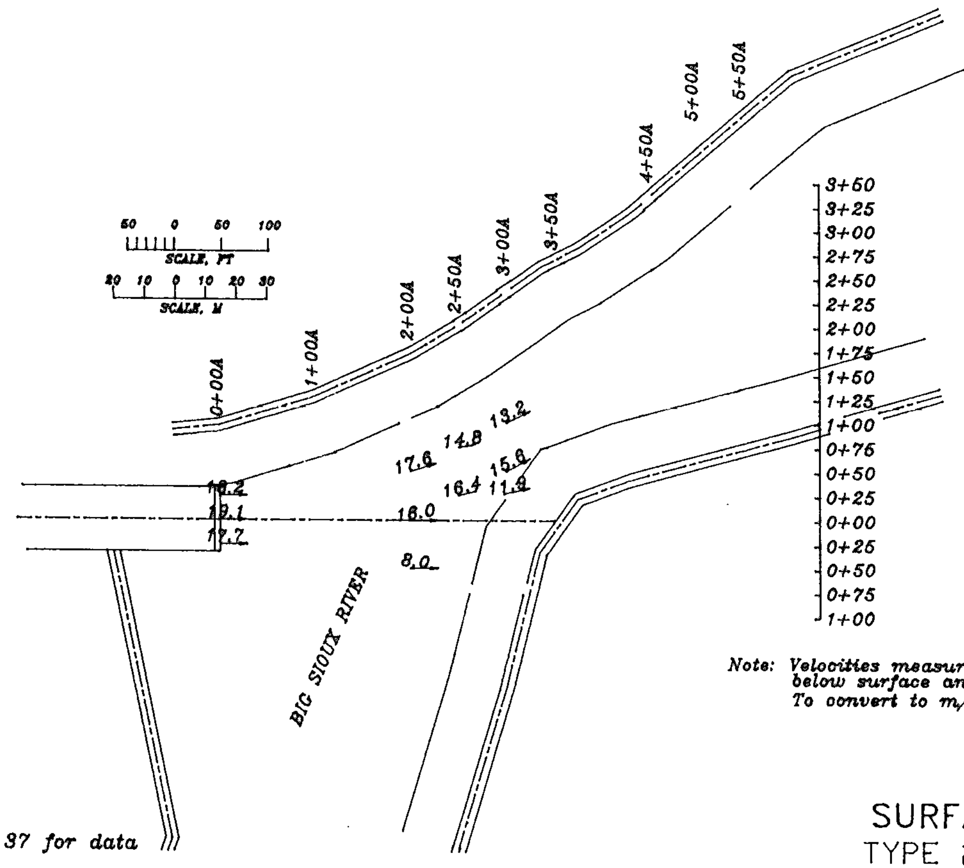
BOTTOM VELOCITIES

TYPE 2 STILLING BASIN

Q_C = 700 CU M/SEC (25,000 CFS)

Q_R = 224 CU M/SEC (8,000 CFS)

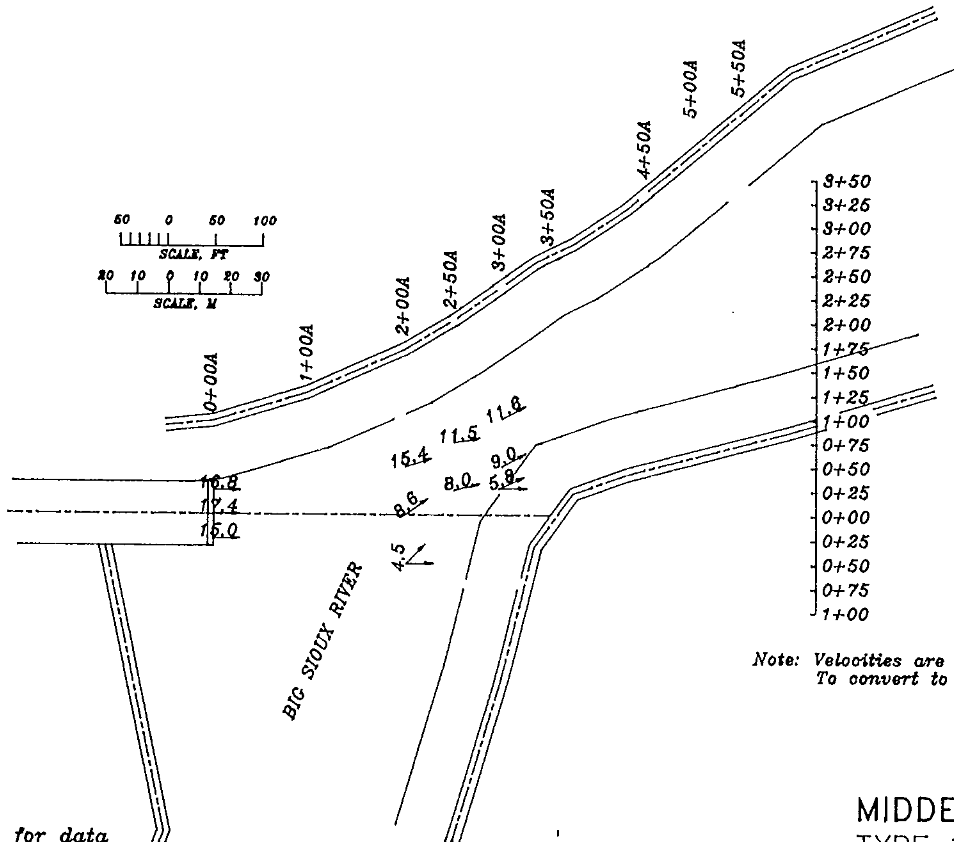
TAILWATER ELEVATION 1326.0



Note: See Table 37 for data

Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

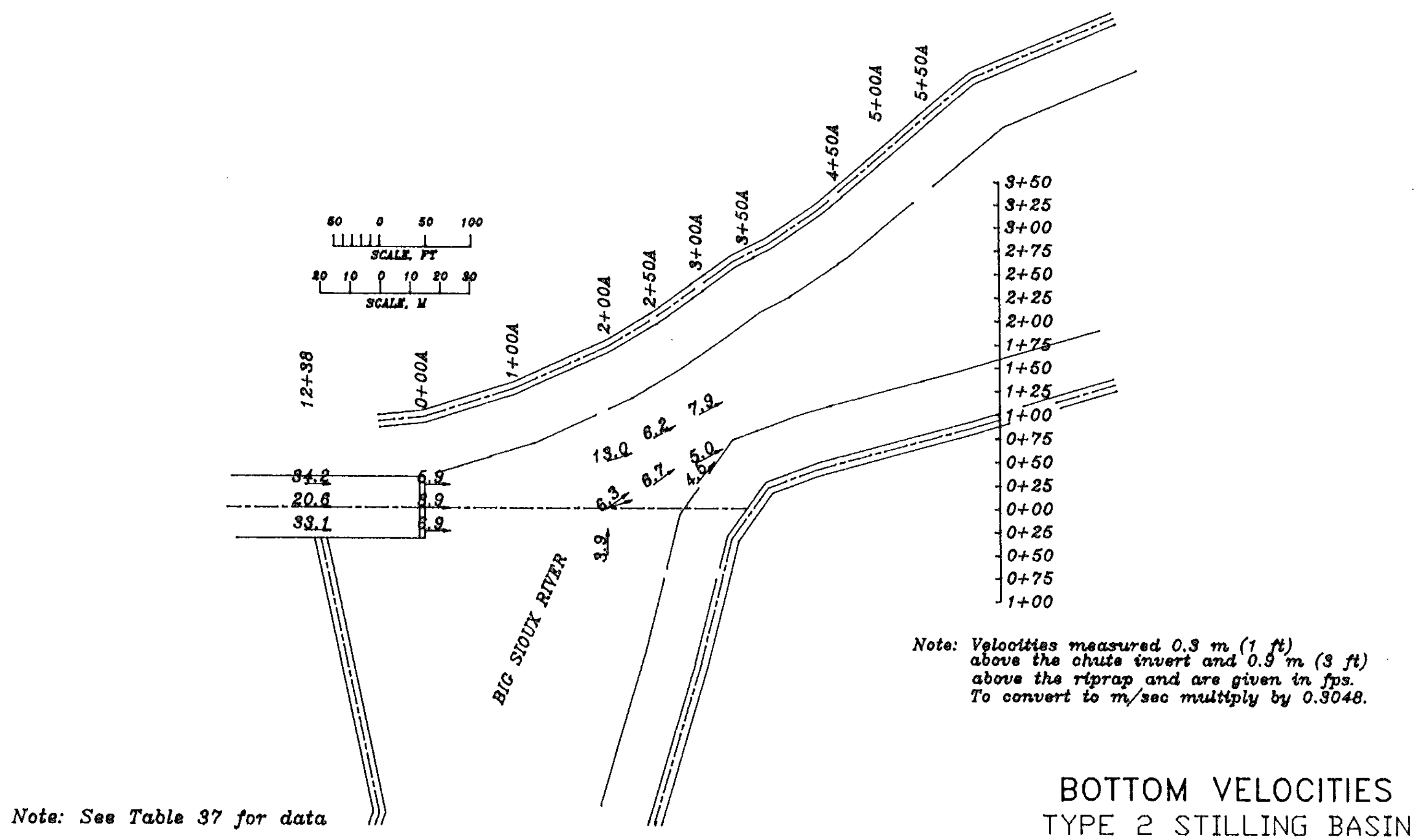
SURFACE VELOCITIES
TYPE 2 STILLING BASIN
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 204 CU M/SEC (7,300 CFS)
TAILWATER ELEVATION 1322.0



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 37 for data

MIDDEPTH VELOCITIES
TYPE 2 STILLING BASIN
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 204 CU M/SEC (7,300 CFS)
TAILWATER ELEVATION 1322.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 37 for data

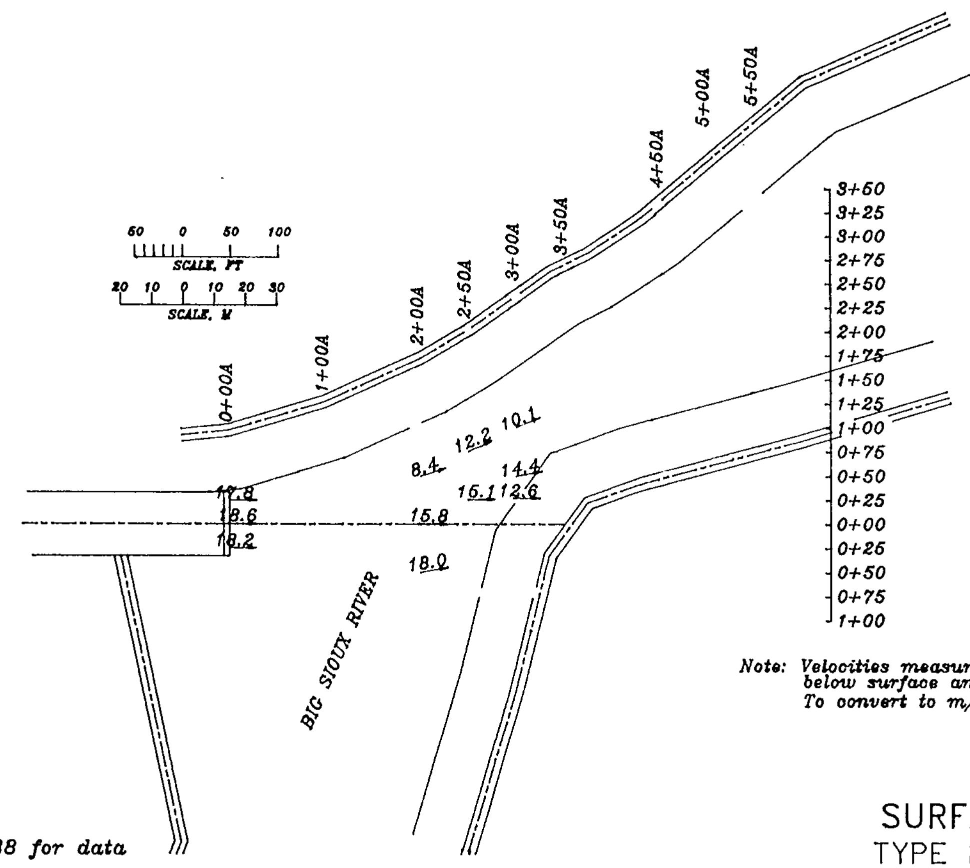
BOTTOM VELOCITIES

TYPE 2 STILLING BASIN

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 204 CU M/SEC (7,300 CFS)

TAILWATER ELEVATION 1322.0



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 38 for data

SURFACE VELOCITIES

TYPE 2 STILLING BASIN

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 204 CU M/SEC (7,300 CFS)

TAILWATER ELEVATION 1328.0

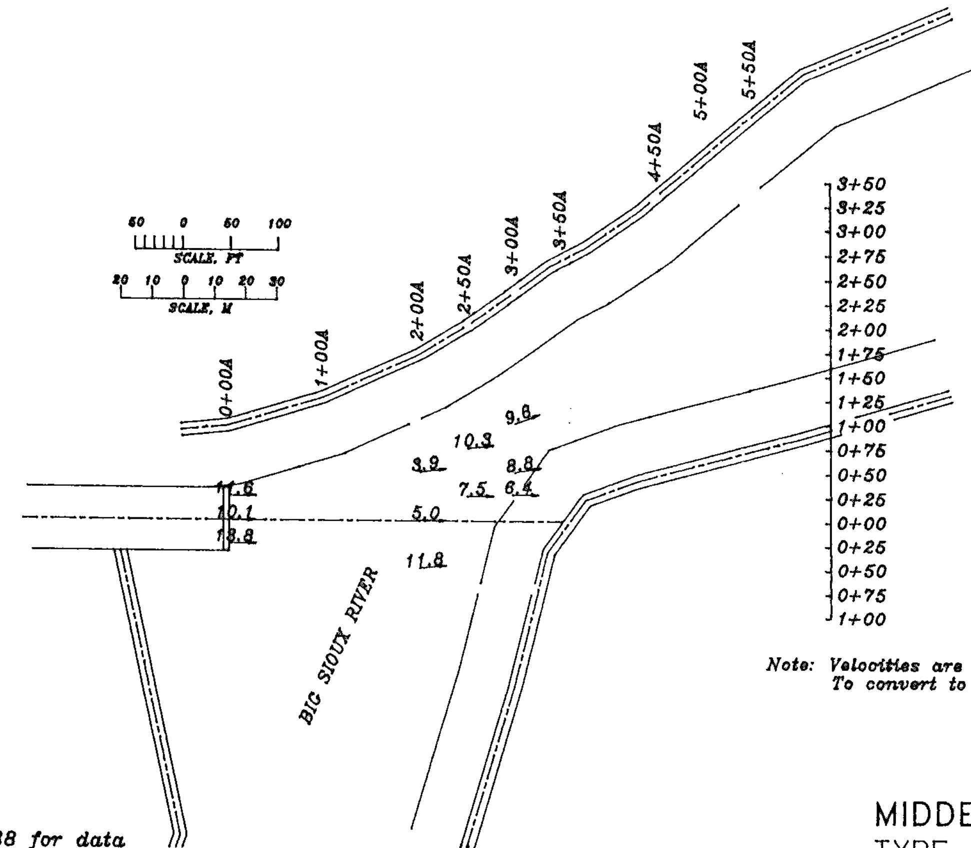
MIDDEPTH VELOCITIES

TYPE 2 STILLING BASIN

Q_C = 812 CU M/SEC (29,000 CFS)

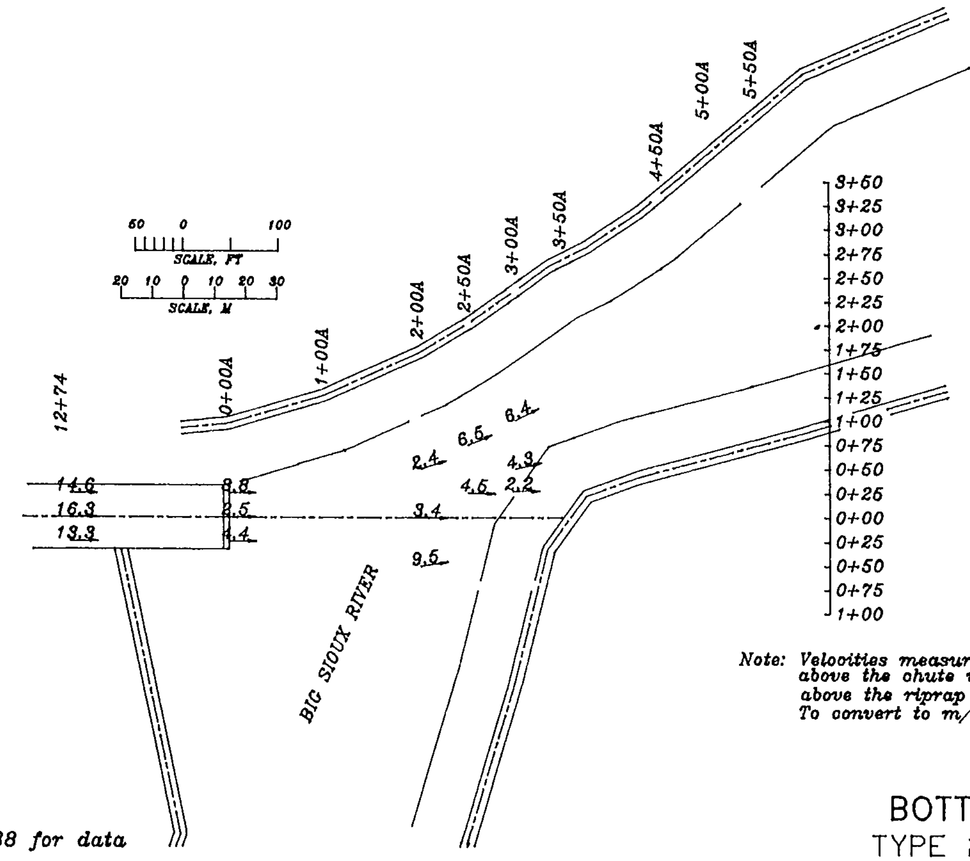
Q_R = 204 CU M/SEC (7,300 CFS)

TAILWATER ELEVATION 1328.0



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

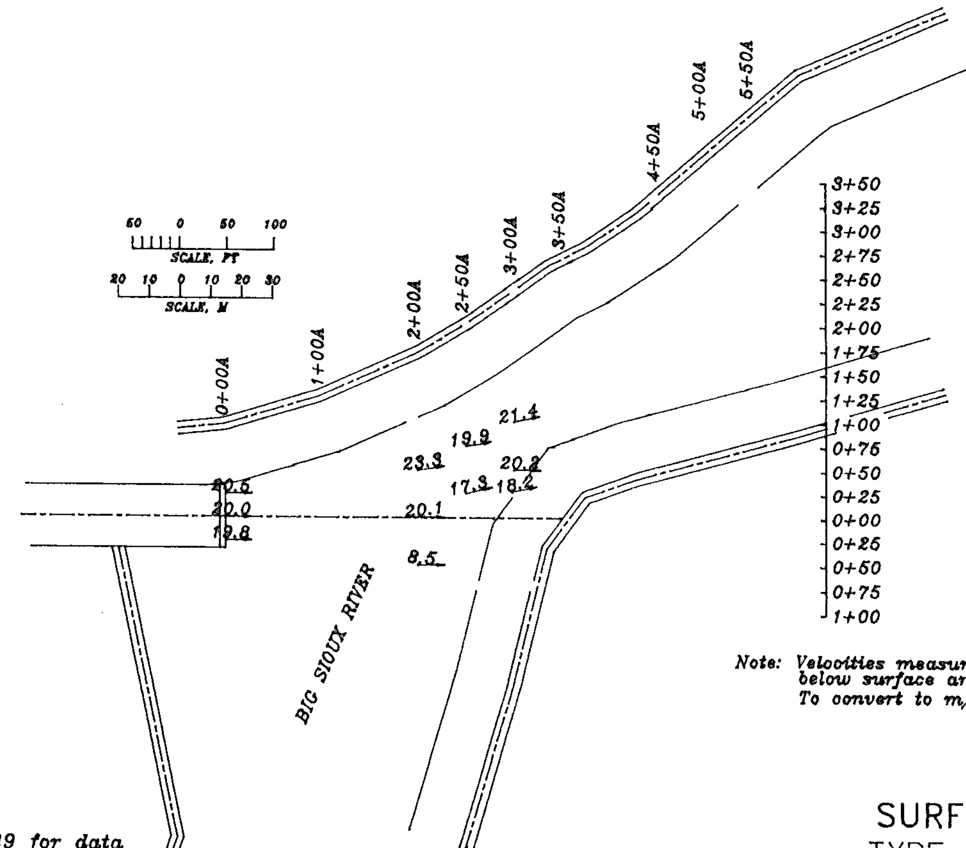
Note: See Table 38 for data



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 38 for data

BOTTOM VELOCITIES
TYPE 2 STILLING BASIN
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 204 CU M/SEC (7,300 CFS)
TAILWATER ELEVATION 1328.0



Note: See Table 39 for data

Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

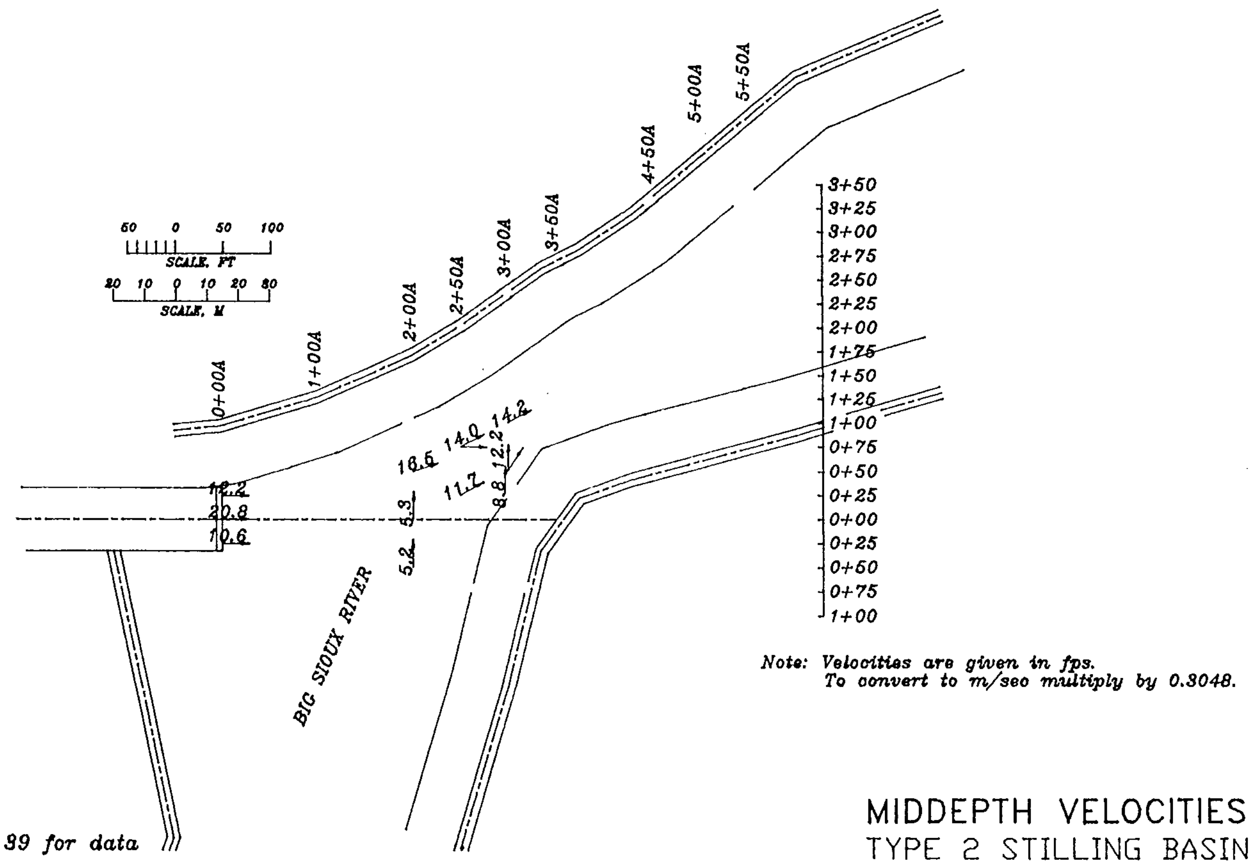
SURFACE VELOCITIES

TYPE 2 STILLING BASIN

Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

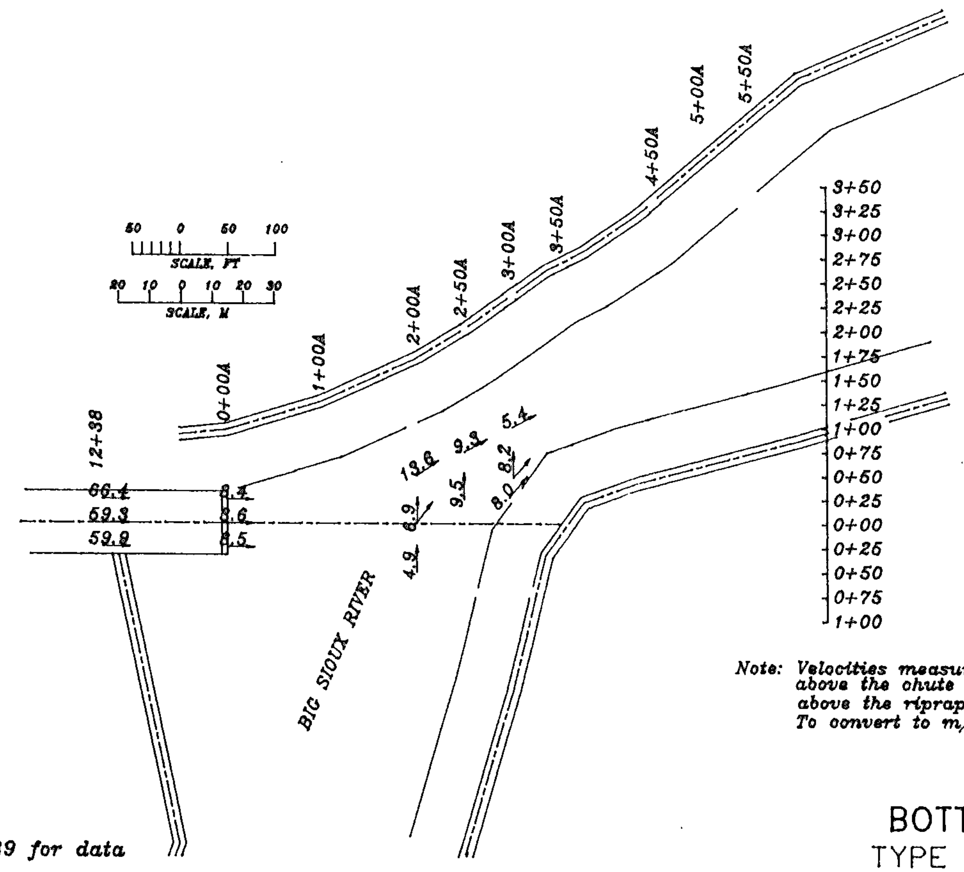
TAILWATER ELEVATION 1326.0



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 39 for data

MIDDEPTH VELOCITIES
TYPE 2 STILLING BASIN
Q_C = 1,044 CU M/SEC (37,300 CFS)
Q_R = 812 CU M/SEC (29,000 CFS)
TAILWATER ELEVATION 1326.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 39 for data

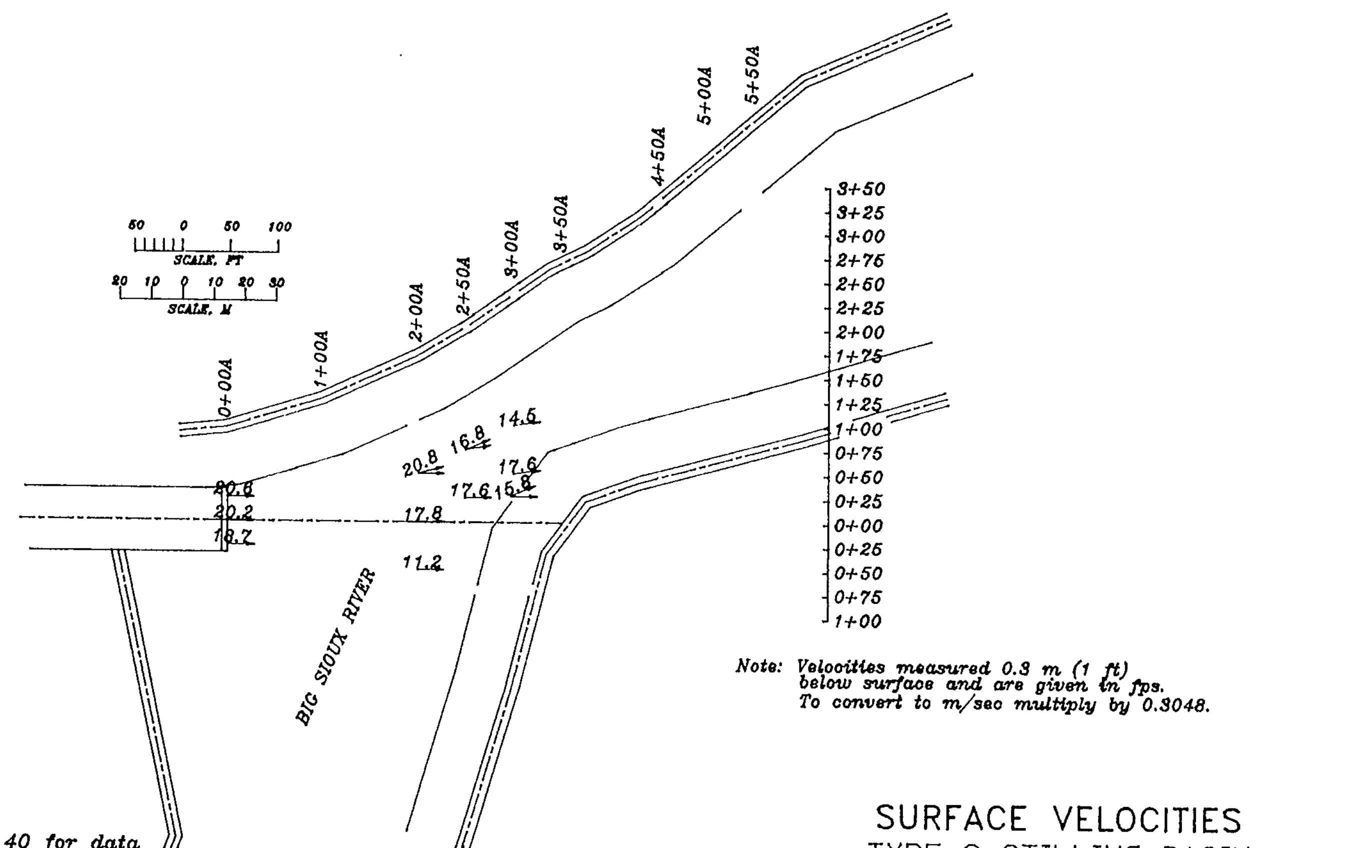
BOTTOM VELOCITIES

TYPE 2 STILLING BASIN

Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

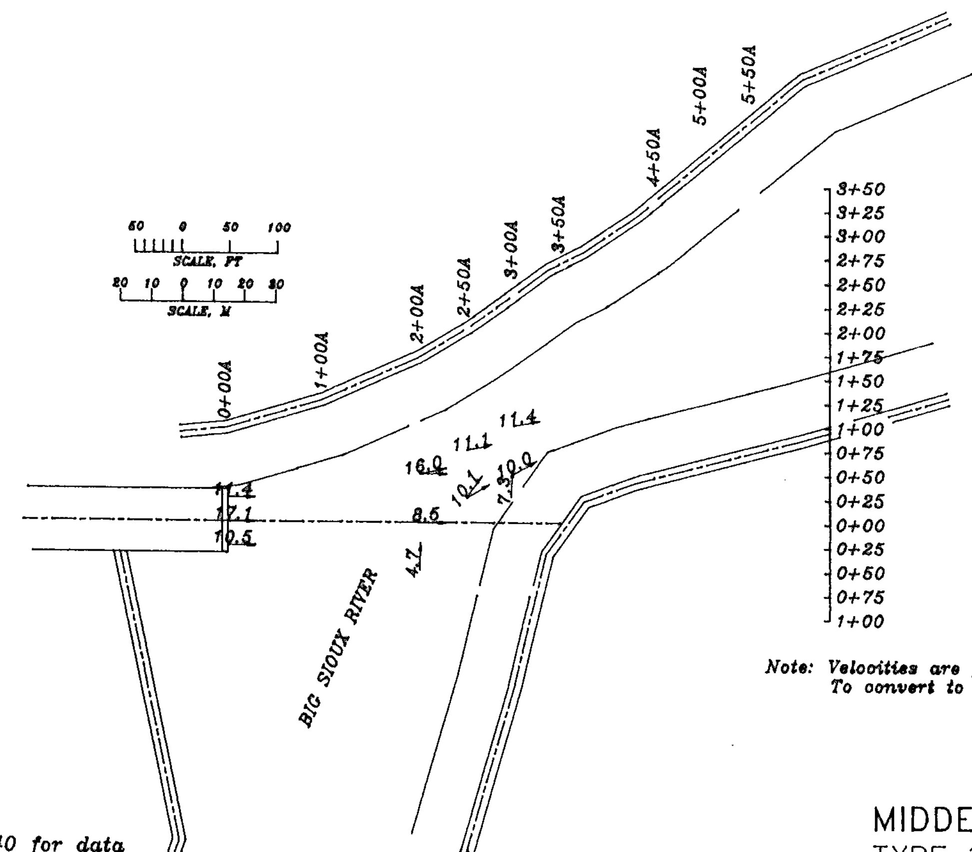
TAILWATER ELEVATION 1326.0



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 40 for data

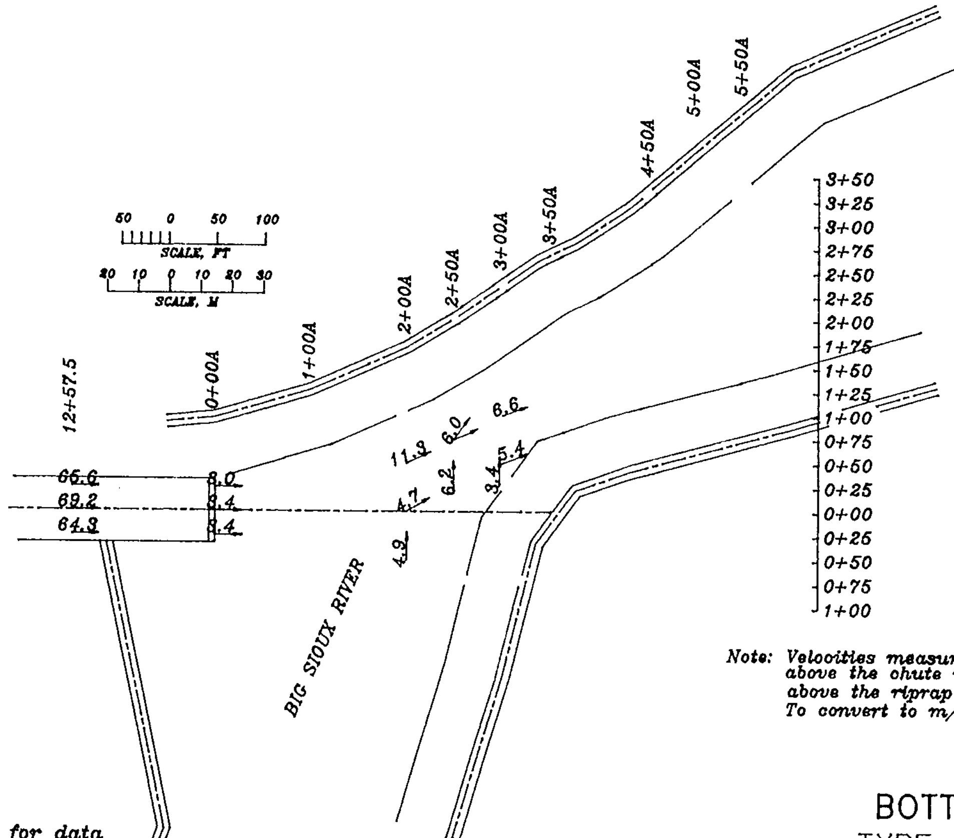
SURFACE VELOCITIES
TYPE 2 STILLING BASIN
Q_C = 1,044 CU M/SEC (37,300 CFS)
Q_R = 812 CU M/SEC (29,000 CFS)
TAILWATER ELEVATION 1330.0



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 40 for data

MIDDEPTH VELOCITIES
TYPE 2 STILLING BASIN
Q_C = 1,044 CU M/SEC (37,300 CFS)
Q_R = 812 CU M/SEC (29,000 CFS)
TAILWATER ELEVATION 1330.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 40 for data

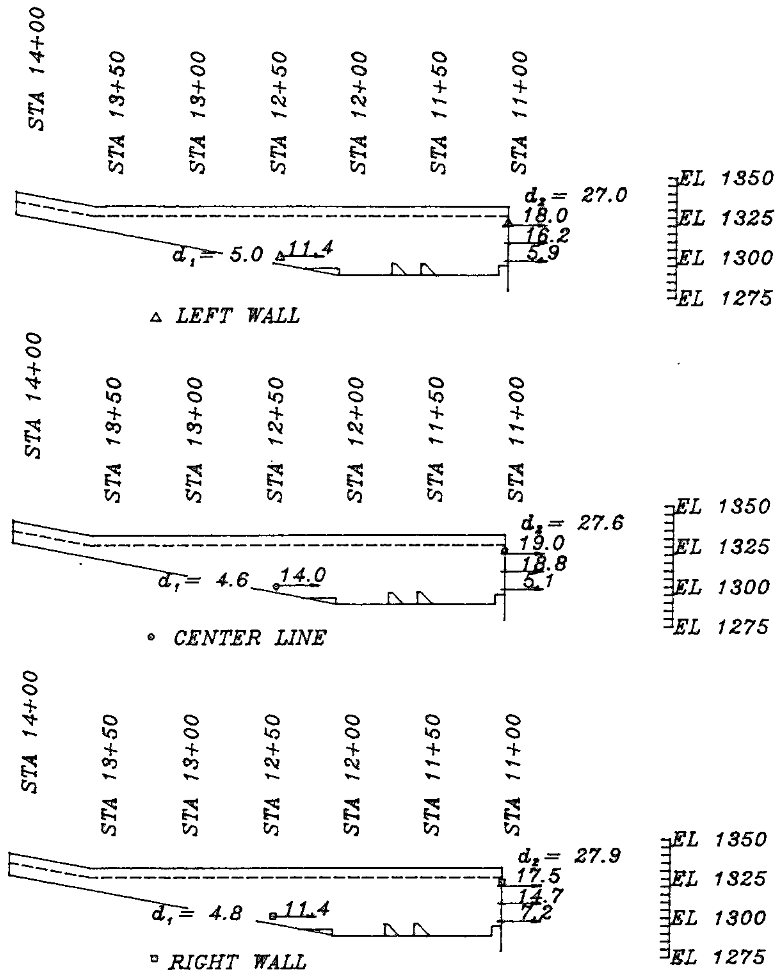
BOTTOM VELOCITIES

TYPE 2 STILLING BASIN

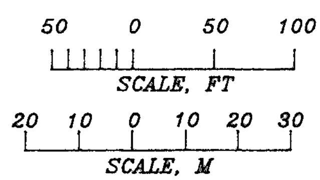
Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

TAILWATER ELEVATION 1330.0

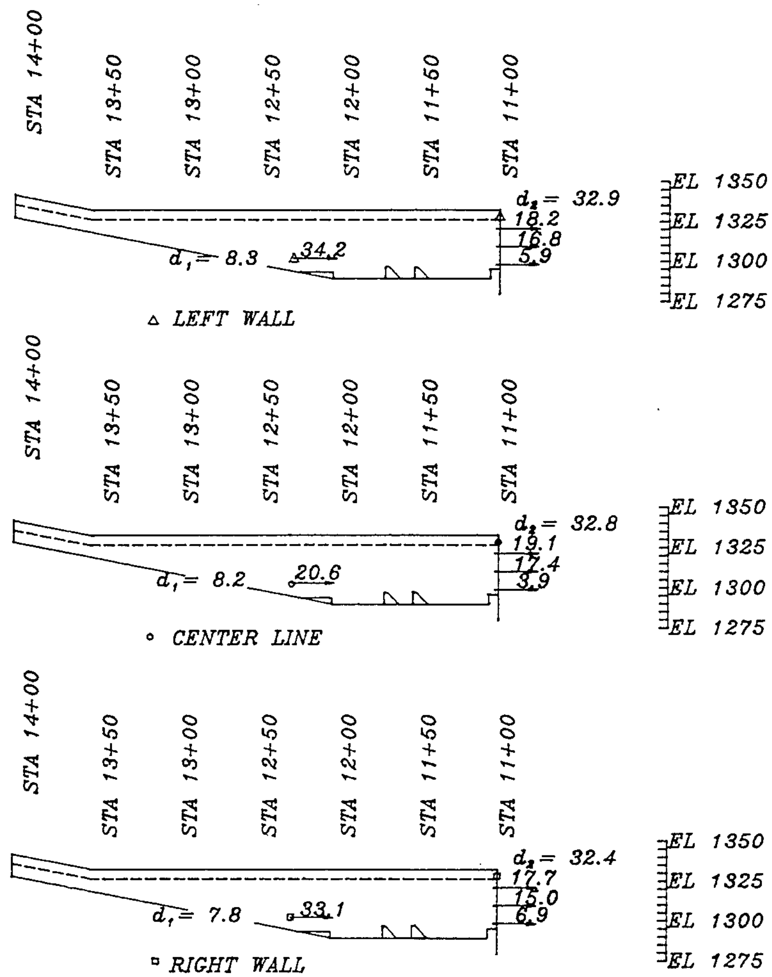


Note: See Table 41 for data

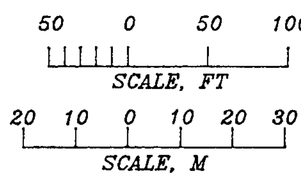


Note: Dimensions given in feet.
To convert to m, multiply by 0.3048.
Velocities measured 0.3 m (1 ft)
below surface and above end sill
and are given in fps. To convert
To convert to m/sec multiply by 0.3048.

D_1, V_1, D_2, V_2
TYPE 2 STILLING BASIN
Q_C = 700 CU M/SEC (25,000 CFS)
Q_R = 224 CU M/SEC (8,000 CFS)
TAILWATER ELEVATION 1320.0



Note: See Table 41 for data



Note: Dimensions given in feet.
To convert to m, multiply by 0.3048.
Velocities measured 0.3 m (1 ft)
below surface and above end sill
and are given in fps. To convert
To convert to m/sec multiply by 0.3048.

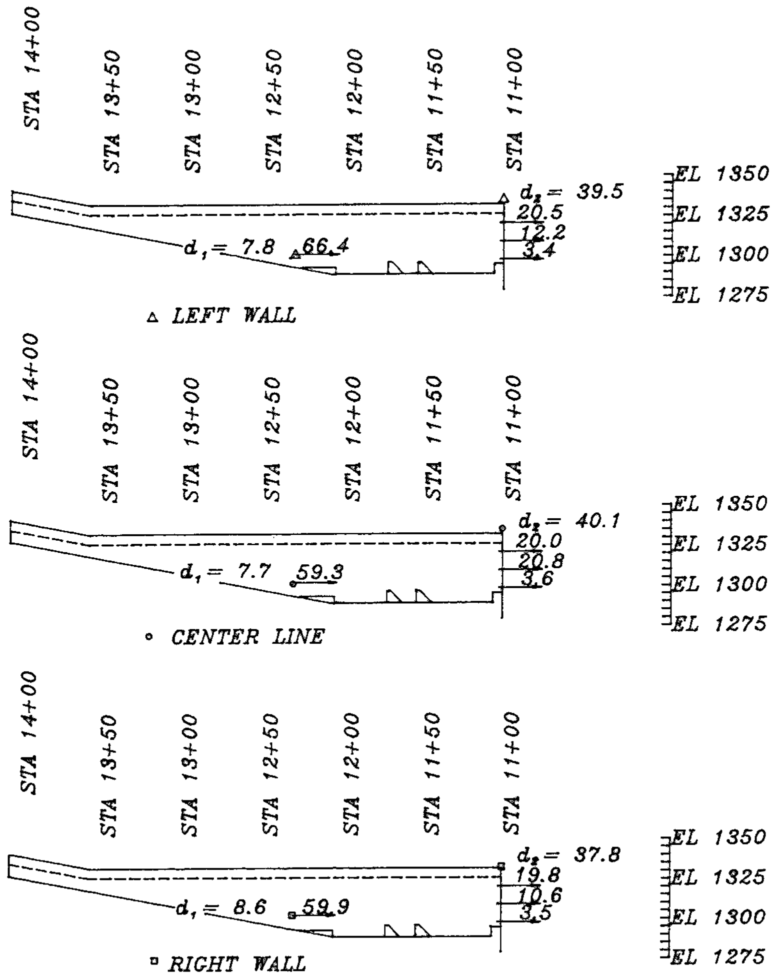
D_1, V_1, D_2, V_2

TYPE 2 STILLING BASIN

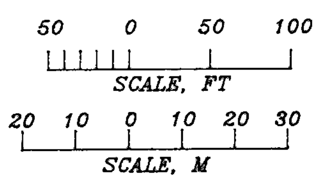
Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 204 CU M/SEC (7,300 CFS)

TAILWATER ELEVATION 1322.0



Note: See Table 41 for data



Note: Dimensions given in feet.
To convert to m, multiply by 0.3048.
Velocities measured 0.3 m (1 ft)
below surface and above end sill
and are given in fps. To convert
To convert to m/sec multiply by 0.3048.

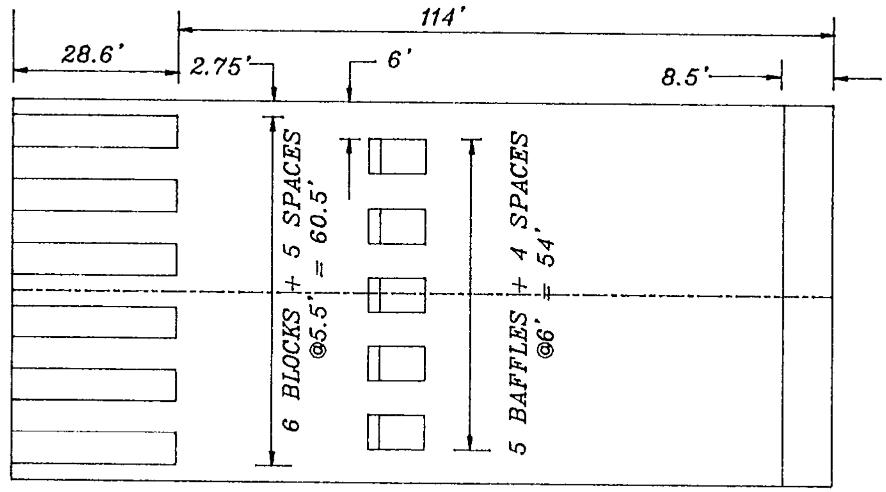
D_1, V_1, D_2, V_2

TYPE 2 STILLING BASIN

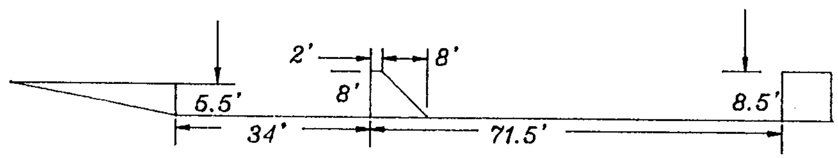
Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

TAILWATER ELEVATION 1326.0



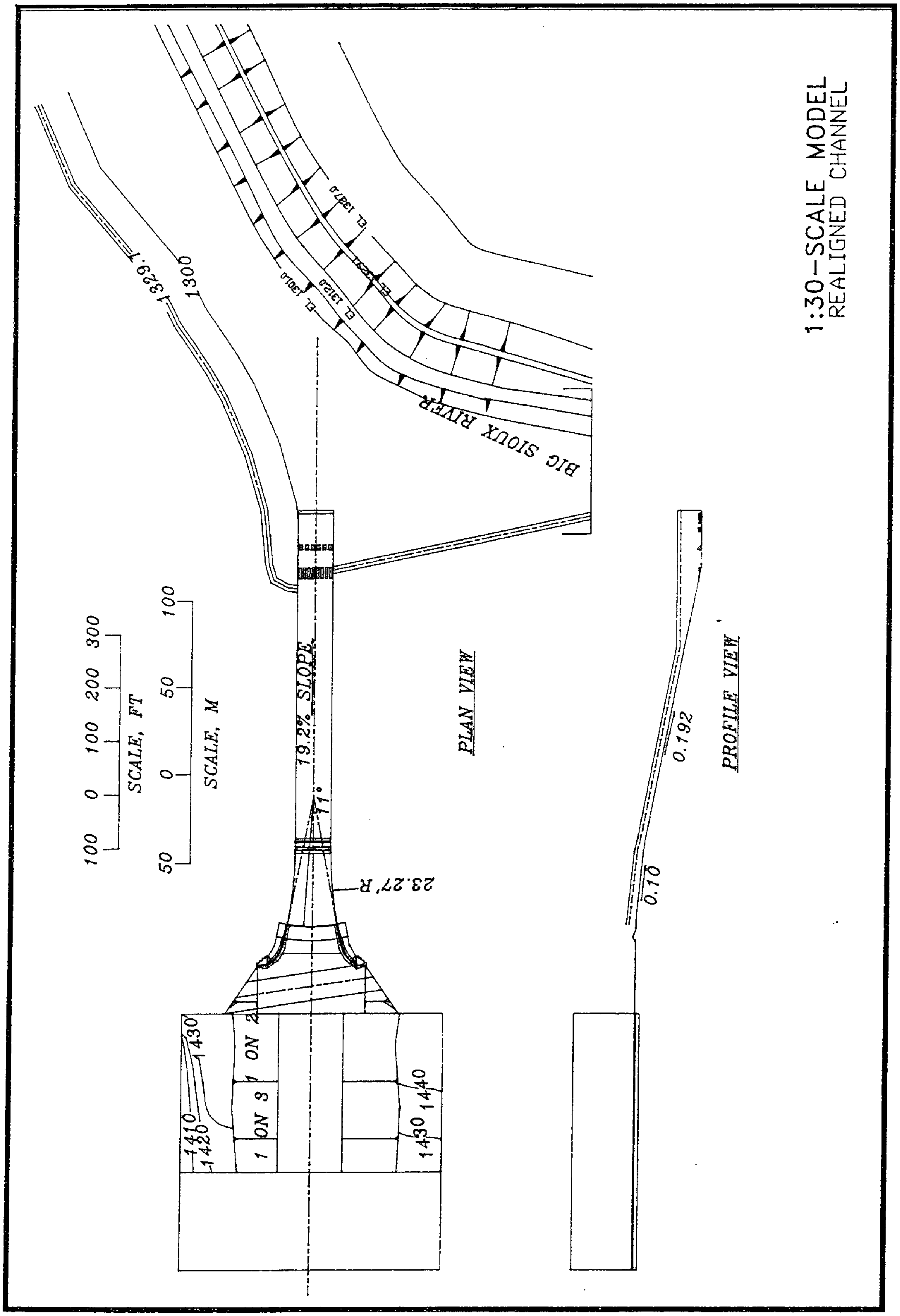
PLAN VIEW

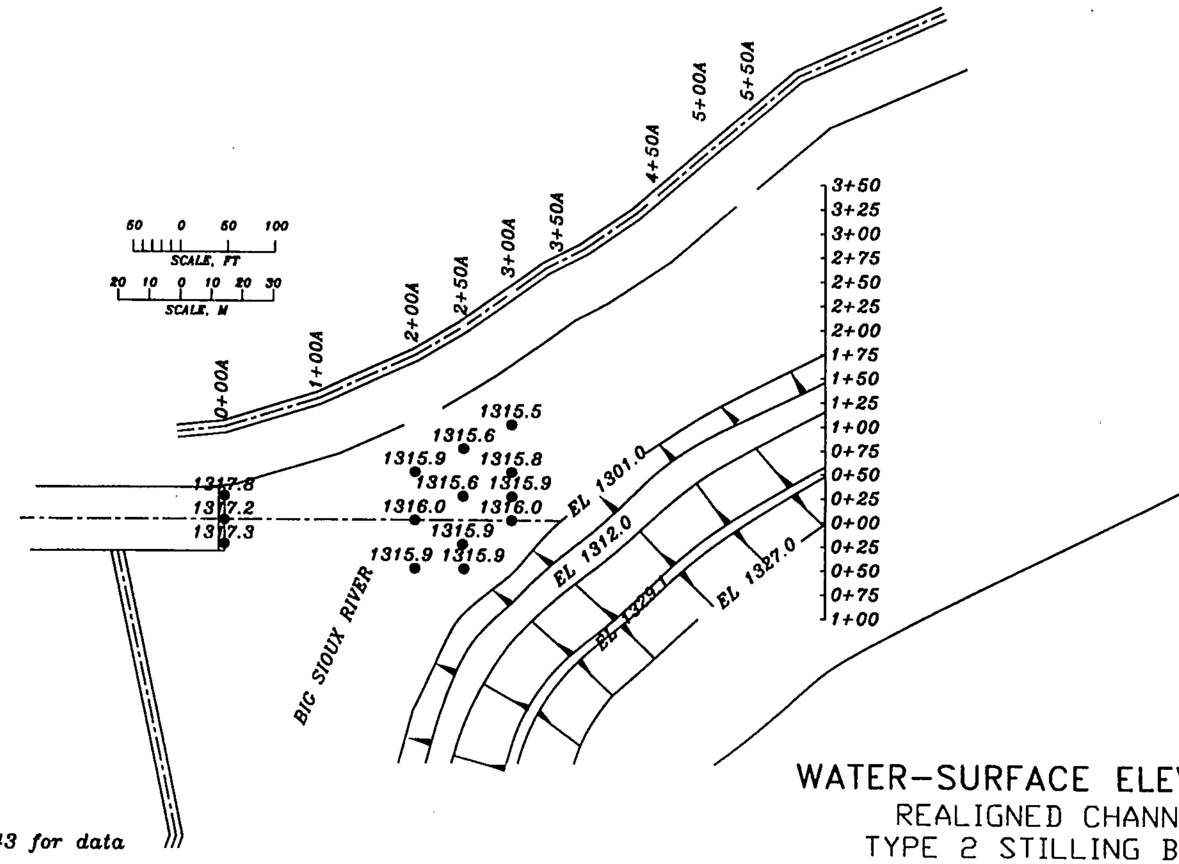


PROFILE VIEW

Note: To convert dimensions to meters, multiply by 0.3048.

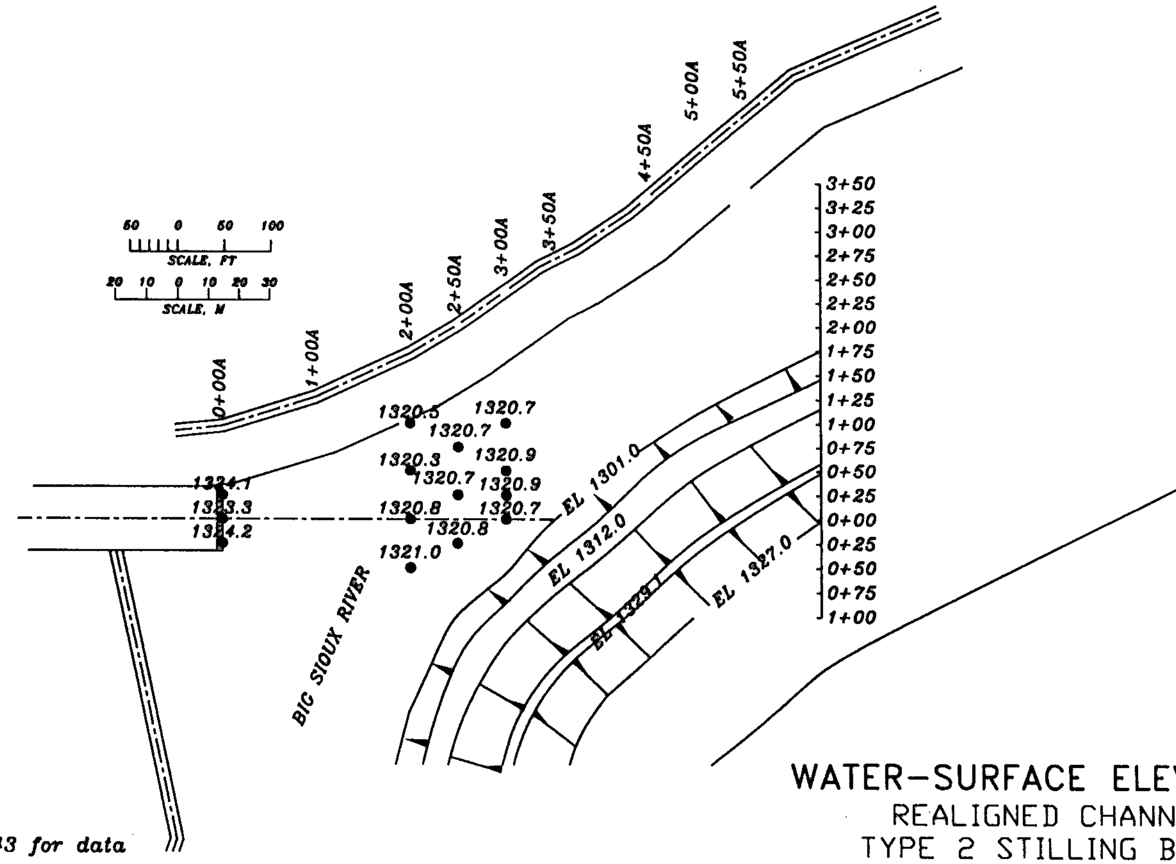
TYPE 3
STILLING BASIN


1:30-SCALE MODEL
REALIGNED CHANNEL
PLAN VIEW
PROFILE VIEW
SCALE, FT
100 0 100 200 300
SCALE, M
50 0 50 100
19.2% SLOPE
11°
23.27' R
BIG SIOUX RIVER
1329.1
1300
EL 1310.0
EL 1312.0
0.192
0.10
1 ON 3
1 ON 2
1410
1420
1430
1440



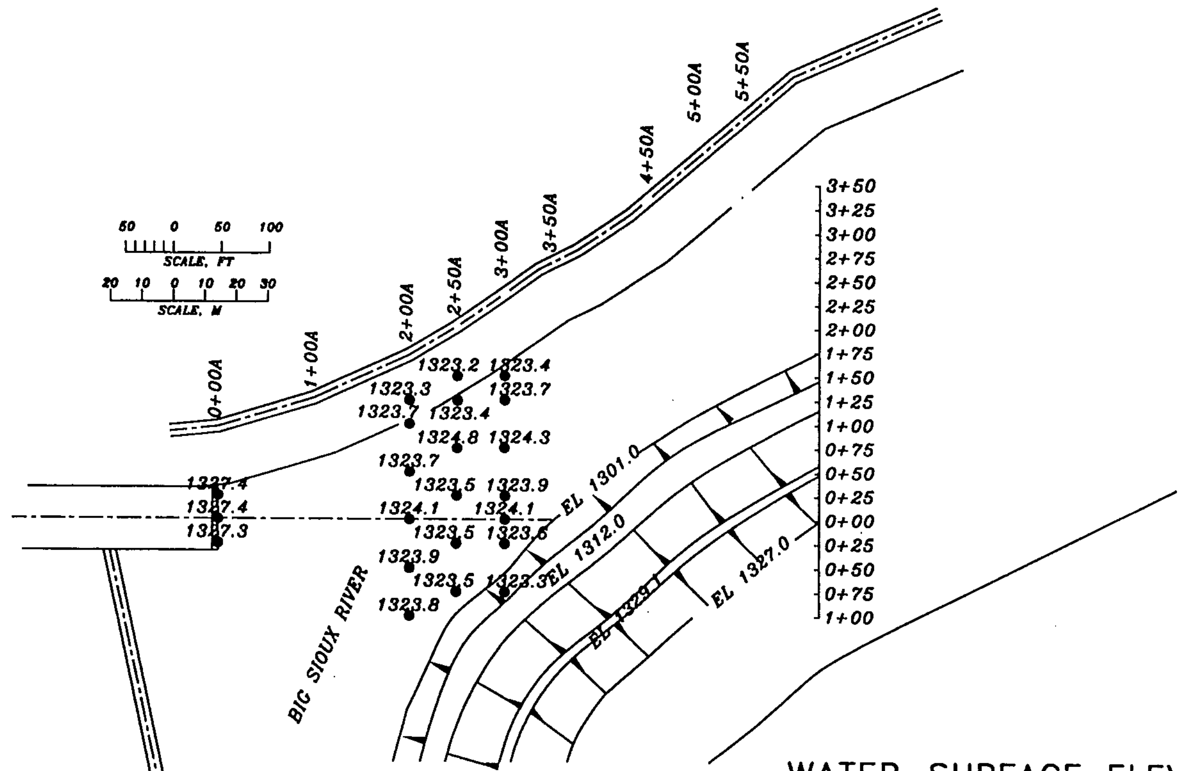
Note: See Table 43 for data

WATER-SURFACE ELEVATIONS
REALIGNED CHANNEL
TYPE 2 STILLING BASIN
Q_C= 356 CU M/SEC (12,700 CFS)
Q_R= 6 CU M/SEC (200 CFS)
TAILWATER ELEVATION 1315.0



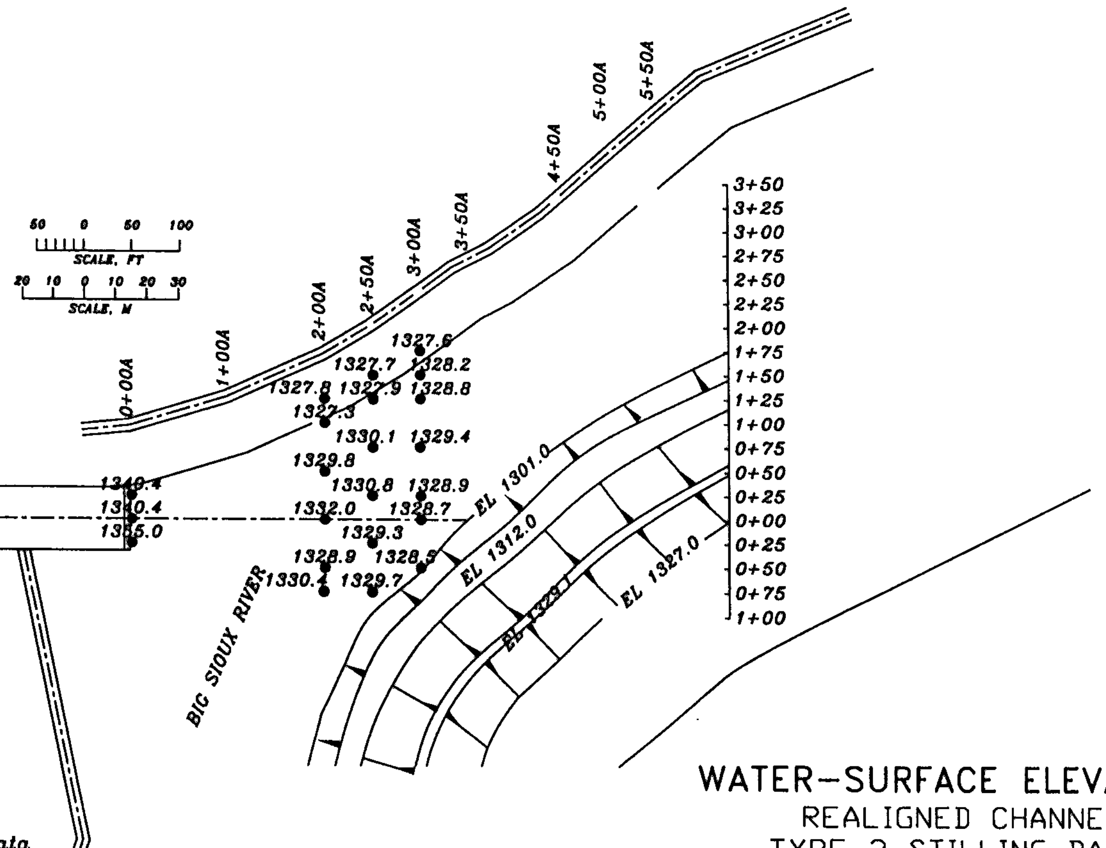
Note: See Table 43 for data

WATER-SURFACE ELEVATIONS
REALIGNED CHANNEL
TYPE 2 STILLING BASIN
Q_C = 591 CU M/SEC (21,100 CFS)
Q_R = 174 CU M/SEC (6,200 CFS)
TAILWATER ELEVATION 1320.2



Note: See Table 43 for data

WATER–SURFACE ELEVATIONS
REALIGNED CHANNEL
TYPE 2 STILLING BASIN
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 204 CU M/SEC (7,300 CFS)
TAILWATER ELEVATION 1322.5



Note: See Table 43 for data

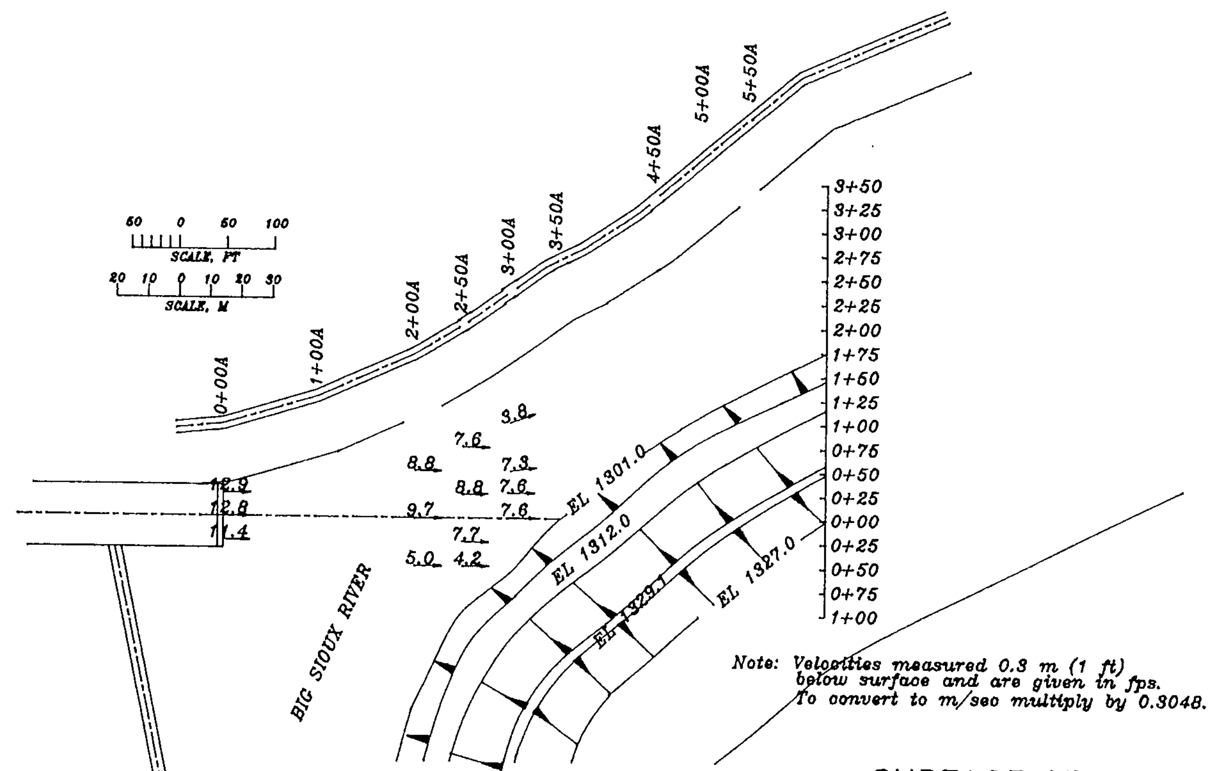
WATER–SURFACE ELEVATIONS

REALIGNED CHANNEL
TYPE 2 STILLING BASIN

Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

TAILWATER ELEVATION 1327.0



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 44 for data

SURFACE VELOCITIES

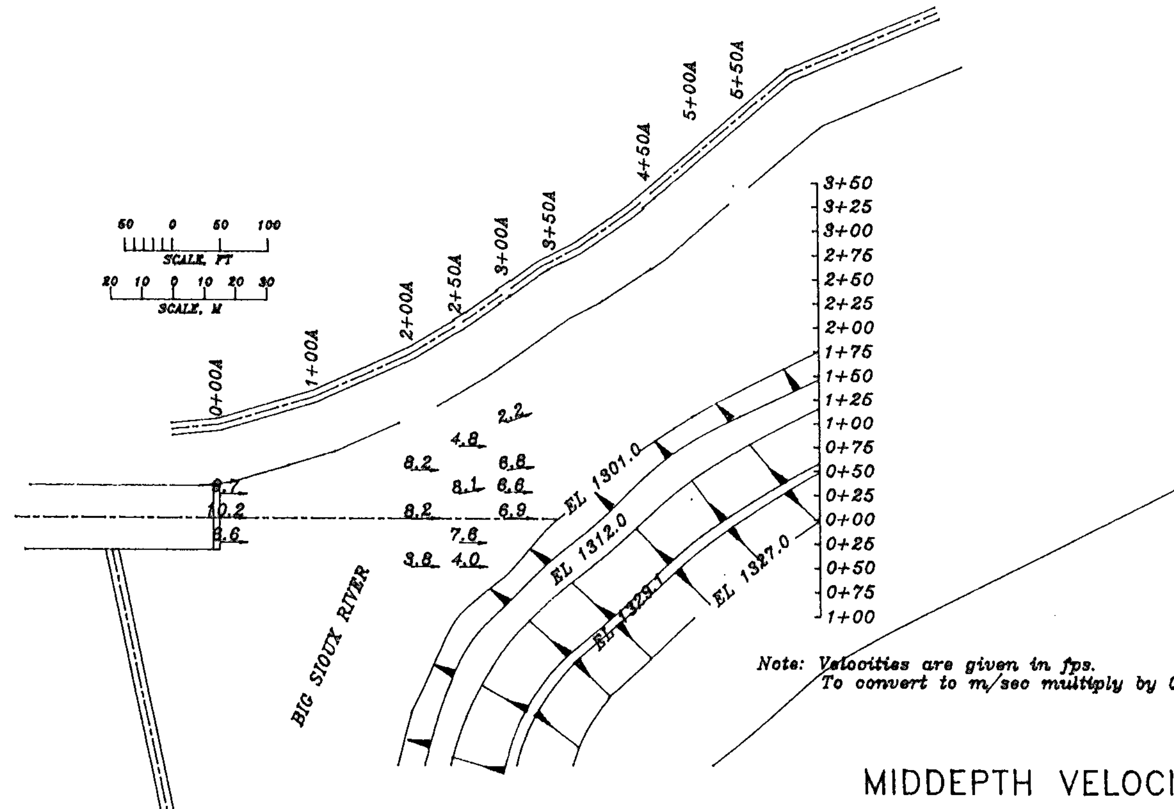
REALIGNED CHANNEL

TYPE 2 STILLING BASIN

Q_C= 356 CU M/SEC (12,700 CFS)

Q_R= 6 CU M/SEC (200 CFS)

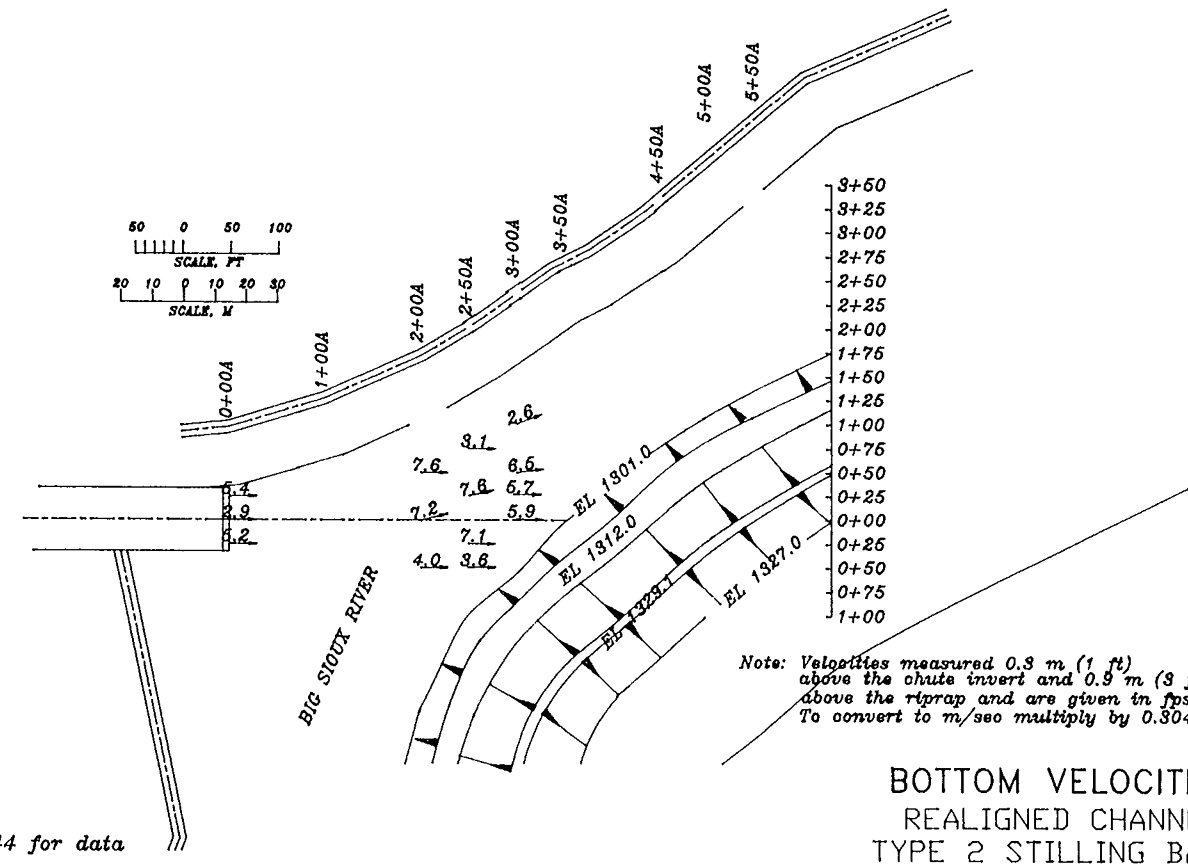
TAILWATER ELEVATION 1315.0



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 44 for data

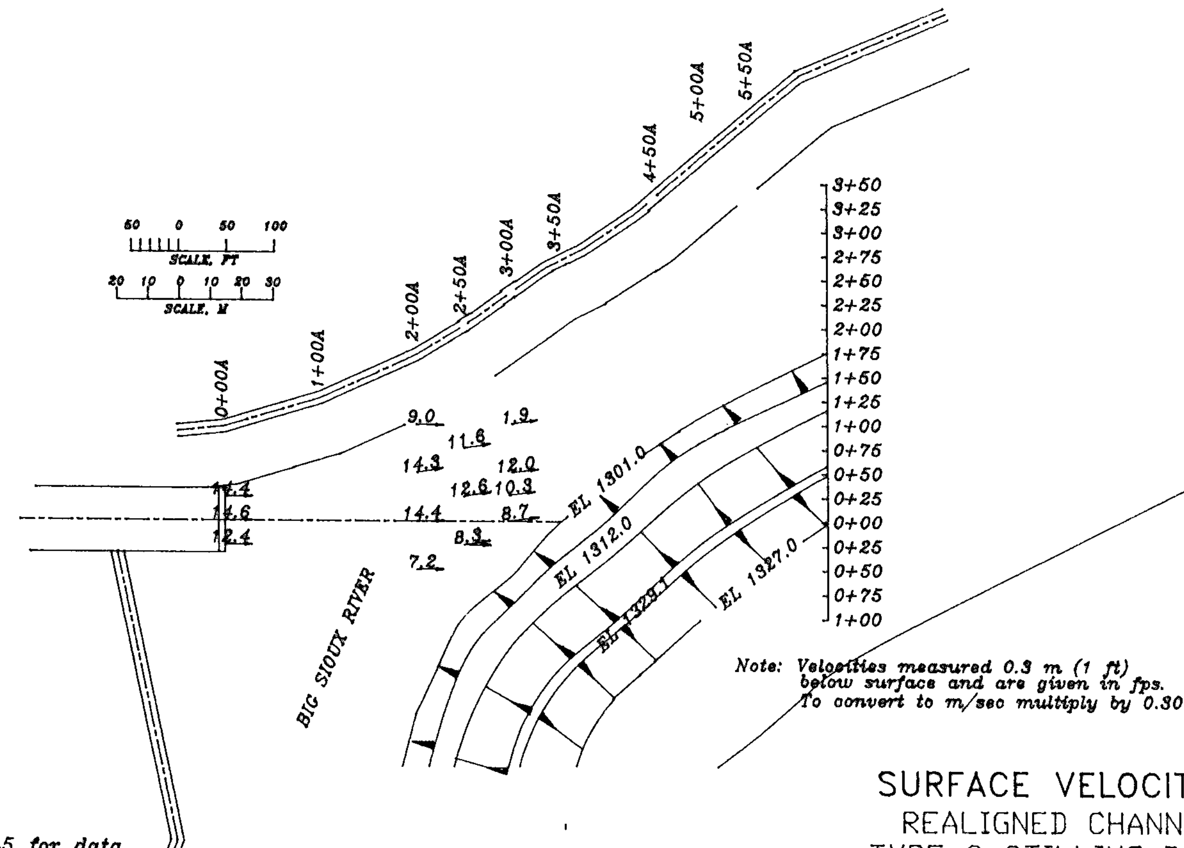
MIDDEPTH VELOCITIES
REALIGNED CHANNEL
TYPE 2 STILLING BASIN
Q_C= 356 CU M/SEC (12,700 CFS)
Q_R= 6 CU M/SEC (200 CFS)
TAILWATER ELEVATION 1315.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 44 for data

BOTTOM VELOCITIES
REALIGNED CHANNEL
TYPE 2 STILLING BASIN
Q_C = 356 CU M/SEC (12,700 CFS)
Q_R = 6 CU M/SEC (200 CFS)
TAILWATER ELEVATION 1315.0



Note: See Table 45 for data

SURFACE VELOCITIES

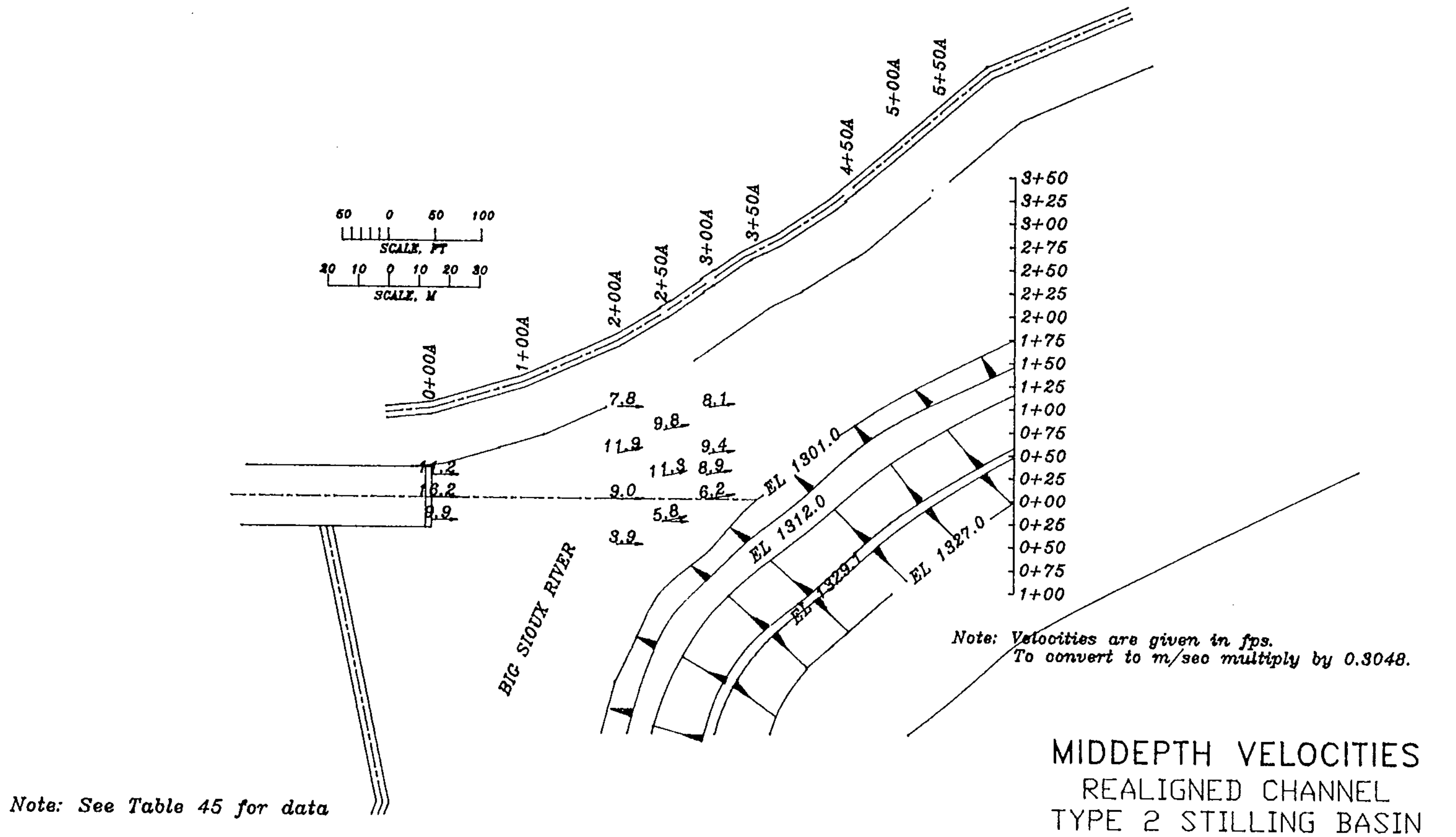
REALIGNED CHANNEL

TYPE 2 STILLING BASIN

Q_C = 591 CU M/SEC (21,100 CFS)

Q_R = 174 CU M/SEC (6,200 CFS)

TAILWATER ELEVATION 1320.2



MIDDEPTH VELOCITIES

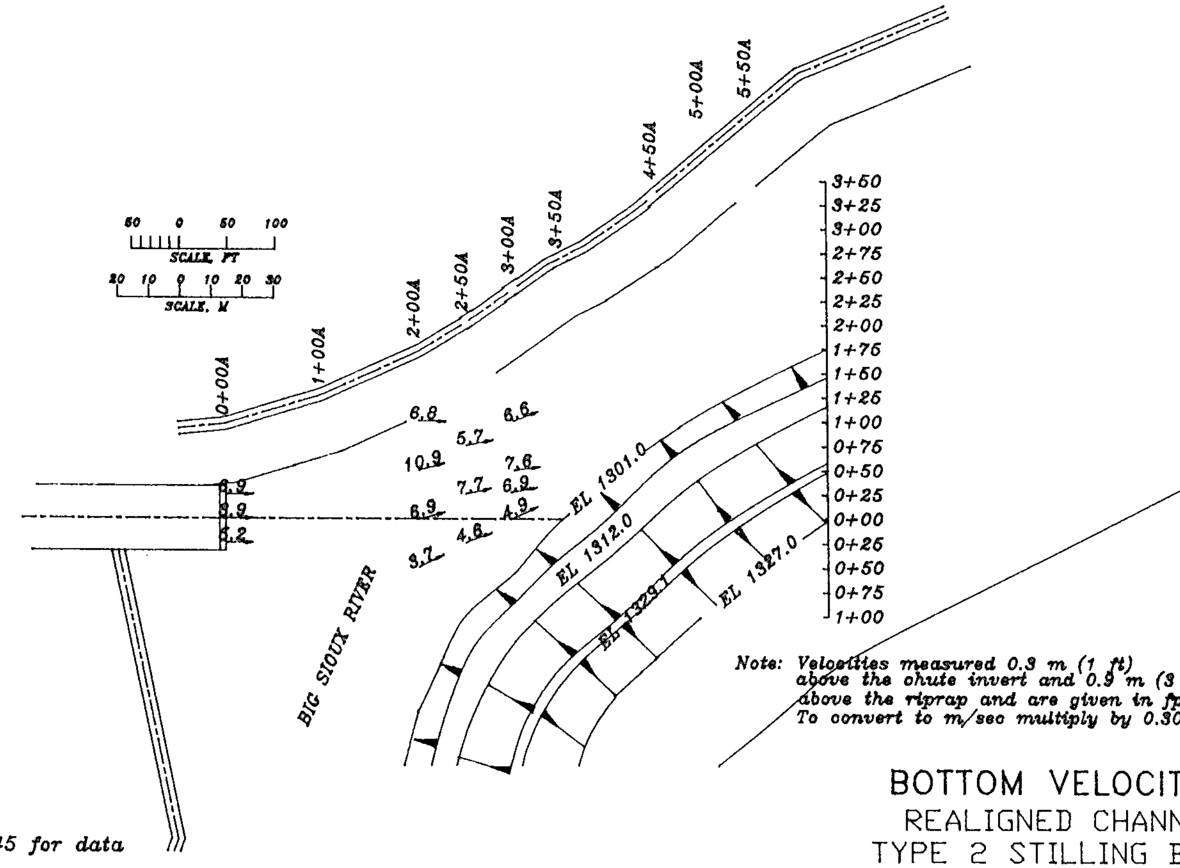
REALIGNED CHANNEL

TYPE 2 STILLING BASIN

Q_C = 591 CU M/SEC (21,100 CFS)

Q_R = 174 CU M/SEC (6,200 CFS)

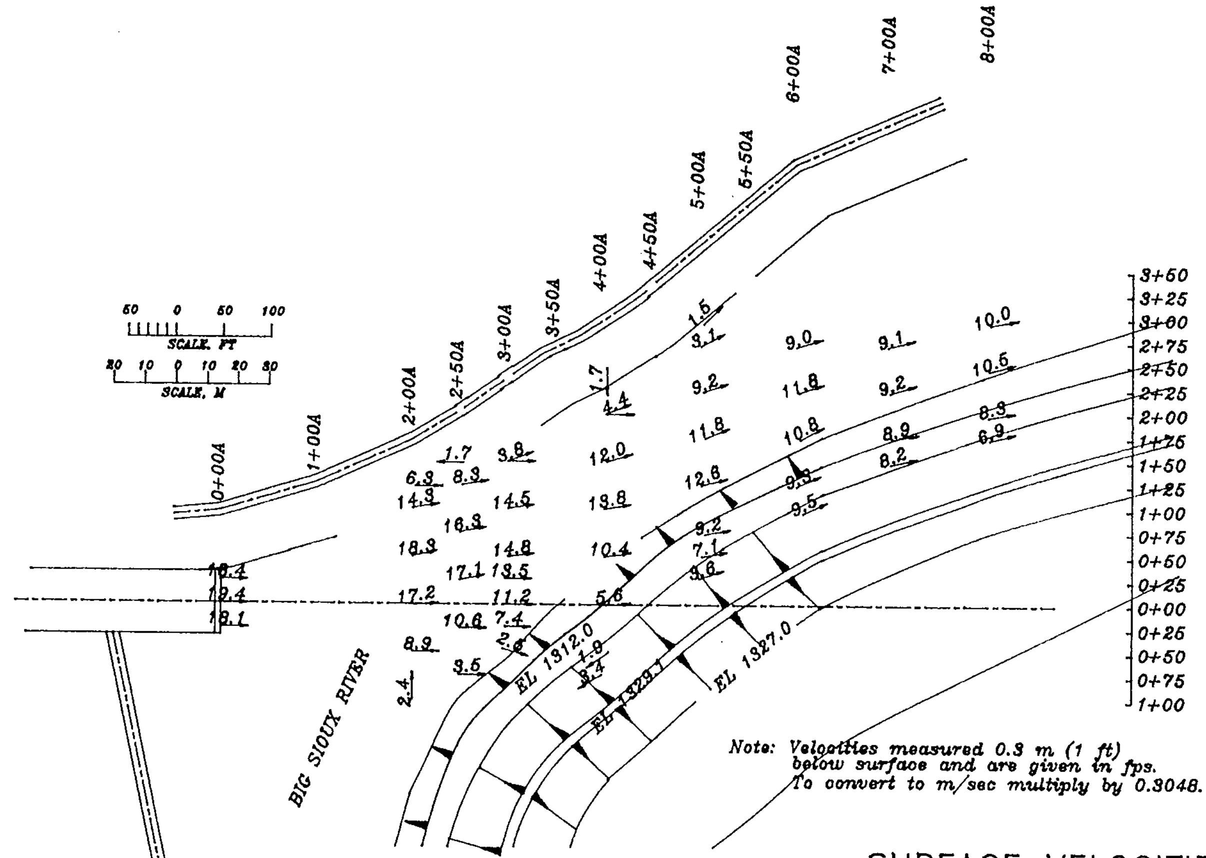
TAILWATER ELEVATION 1320.2



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 45 for data

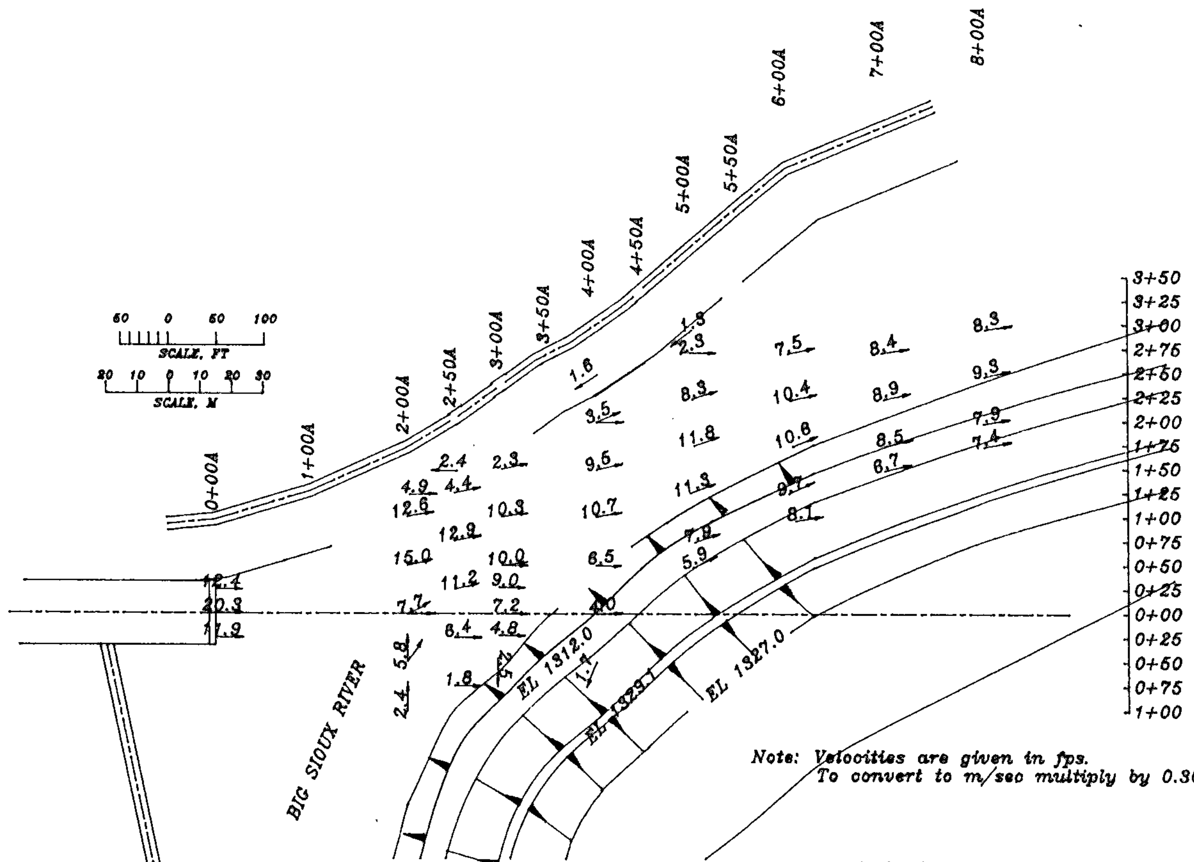
BOTTOM VELOCITIES
REALIGNED CHANNEL
TYPE 2 STILLING BASIN
Q_C = 591 CU M/SEC (21,100 CFS)
Q_R = 174 CU M/SEC (6,200 CFS)
TAILWATER ELEVATION 1320.2



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 46 for data

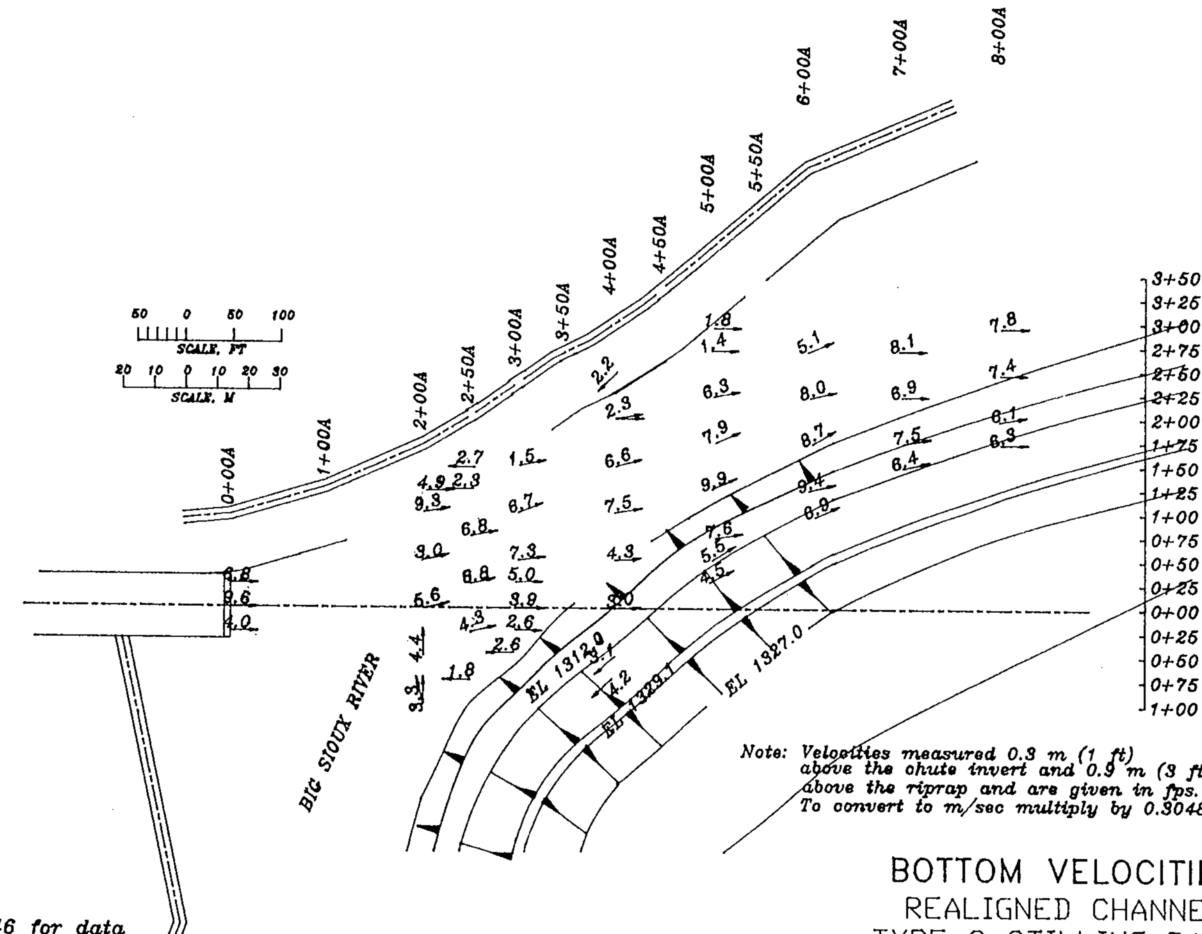
SURFACE VELOCITIES
REALIGNED CHANNEL
TYPE 2 STILLING BASIN
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 204 CU M/SEC (7,300 CFS)
TAILWATER ELEVATION 1322.5



Note: Velocities are given in fps.
To convert to m/sec multiply by 0.3048.

Note: See Table 46 for data

MIDDEPTH VELOCITIES
REALIGNED CHANNEL
TYPE 2 STILLING BASIN
Q_C = 812 CU M/SEC (29,000 CFS)
Q_R = 204 CU M/SEC (7,300 CFS)
TAILWATER ELEVATION 1322.5



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 46 for data

BOTTOM VELOCITIES

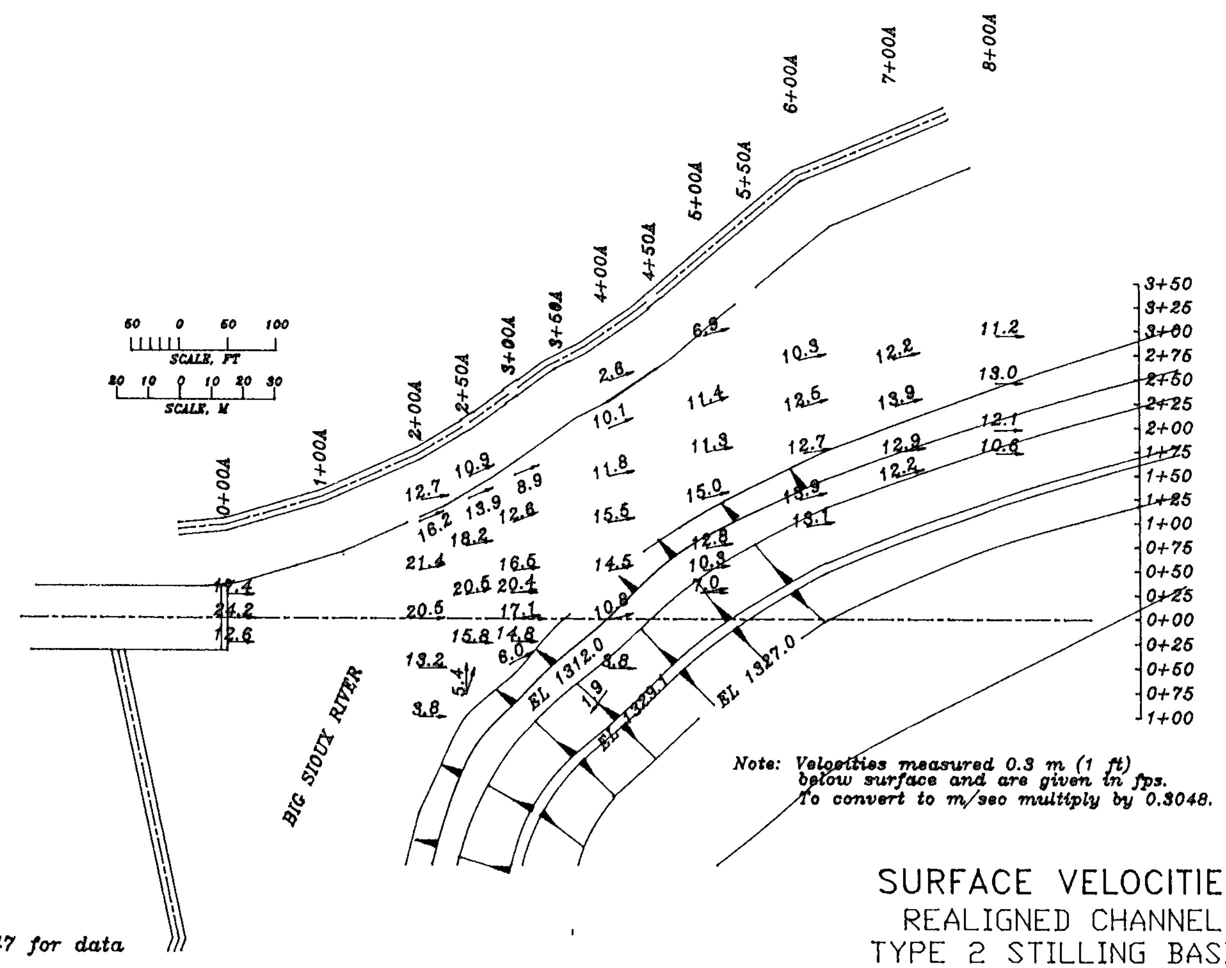
REALIGNED CHANNEL

TYPE 2 STILLING BASIN

Q_C = 812 CU M/SEC (29,000 CFS)

Q_R = 204 CU M/SEC (7,300 CFS)

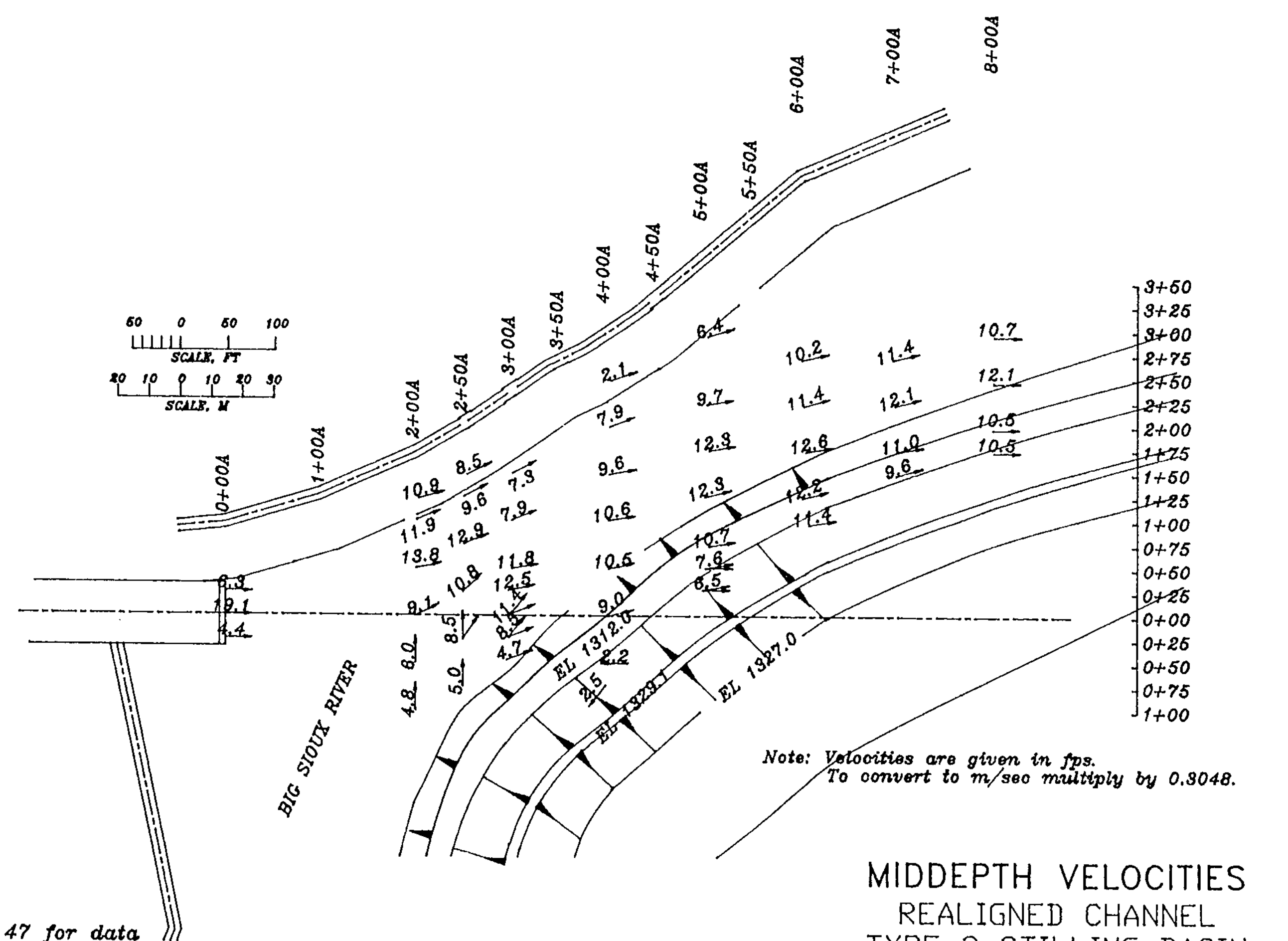
TAILWATER ELEVATION 1322.5



Note: Velocities measured 0.3 m (1 ft) below surface and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 47 for data

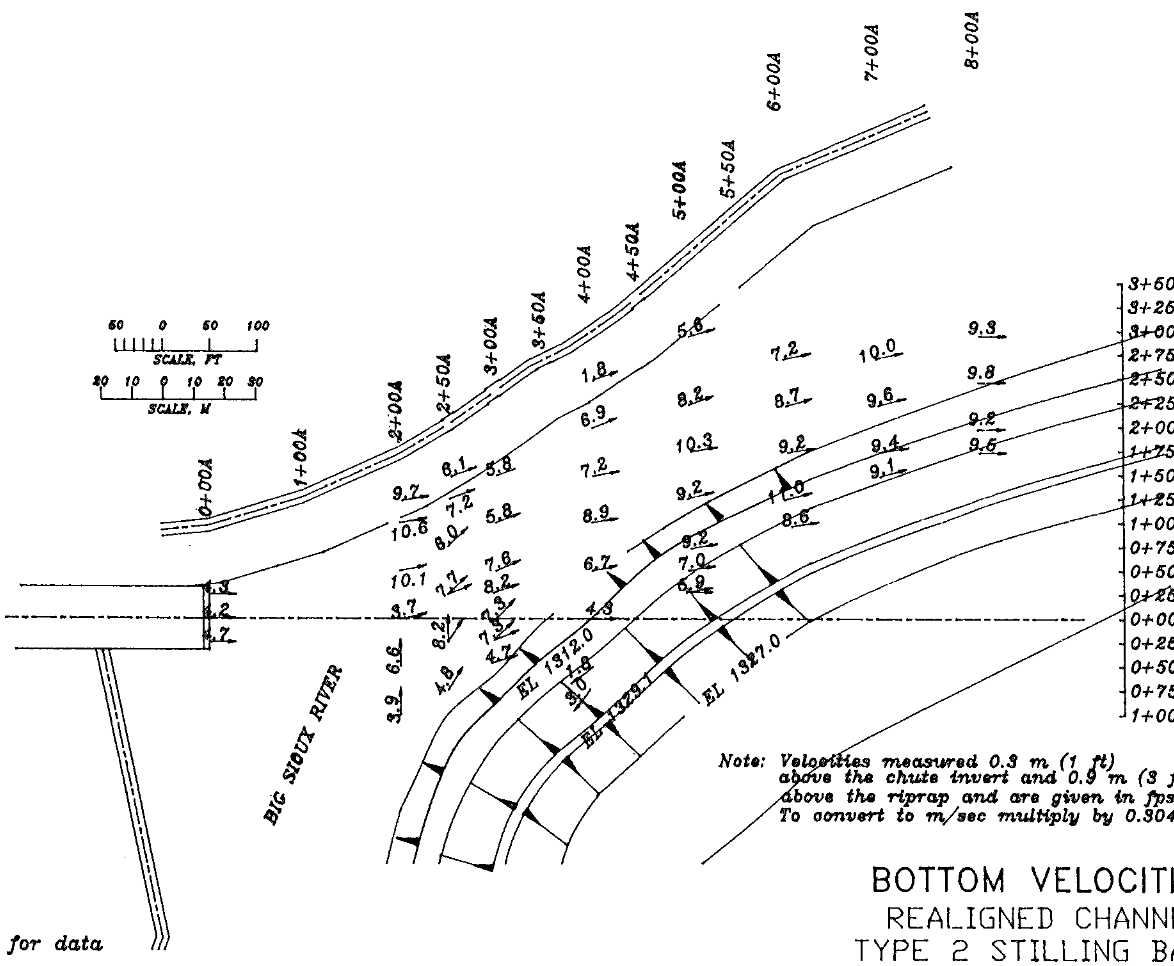
SURFACE VELOCITIES
REALIGNED CHANNEL
TYPE 2 STILLING BASIN
Q_C = 1,044 CU M/SEC (37,300 CFS)
Q_R = 812 CU M/SEC (29,000 CFS)
TAILWATER ELEVATION 1327.0



Note: Velocities are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 47 for data

MIDDEPTH VELOCITIES
REALIGNED CHANNEL
TYPE 2 STILLING BASIN
Q_C = 1,044 CU M/SEC (37,300 CFS)
Q_R = 812 CU M/SEC (29,000 CFS)
TAILWATER ELEVATION 1327.0



Note: Velocities measured 0.3 m (1 ft) above the chute invert and 0.9 m (3 ft) above the riprap and are given in fps. To convert to m/sec multiply by 0.3048.

Note: See Table 47 for data

BOTTOM VELOCITIES

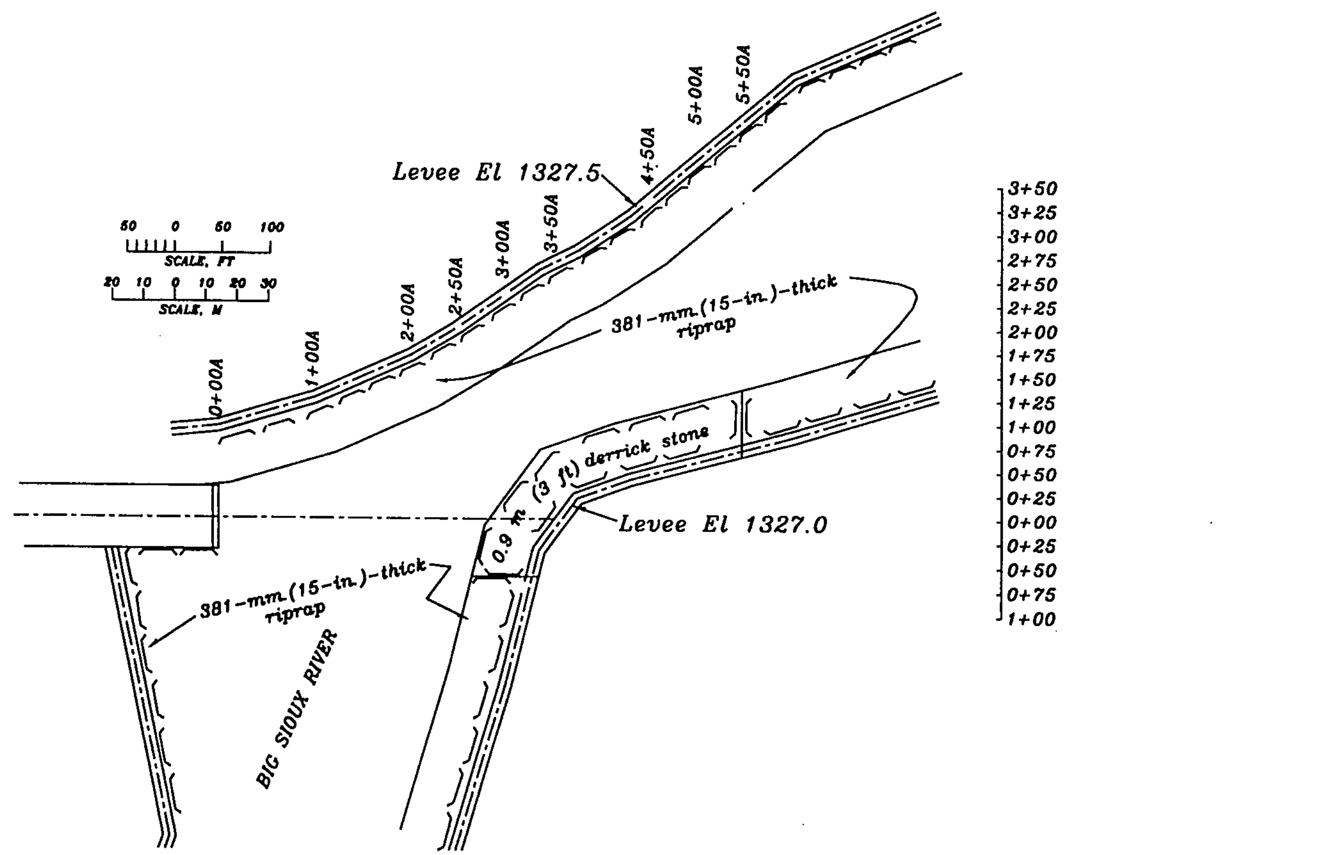
REALIGNED CHANNEL

TYPE 2 STILLING BASIN

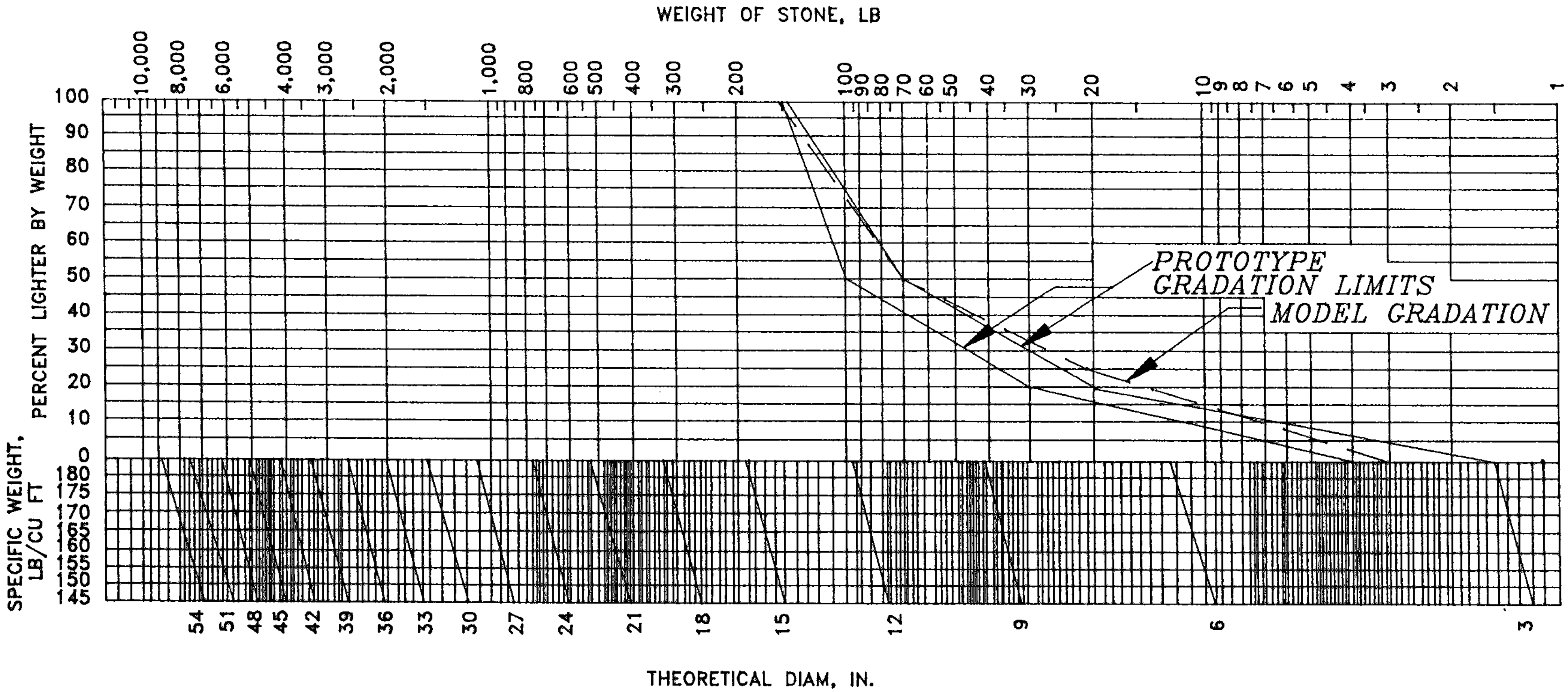
Q_C = 1,044 CU M/SEC (37,300 CFS)

Q_R = 812 CU M/SEC (29,000 CFS)

TAILWATER ELEVATION 1327.0



TYPE 1 RIPRAP DETAIL
EXISTING CONDITIONS

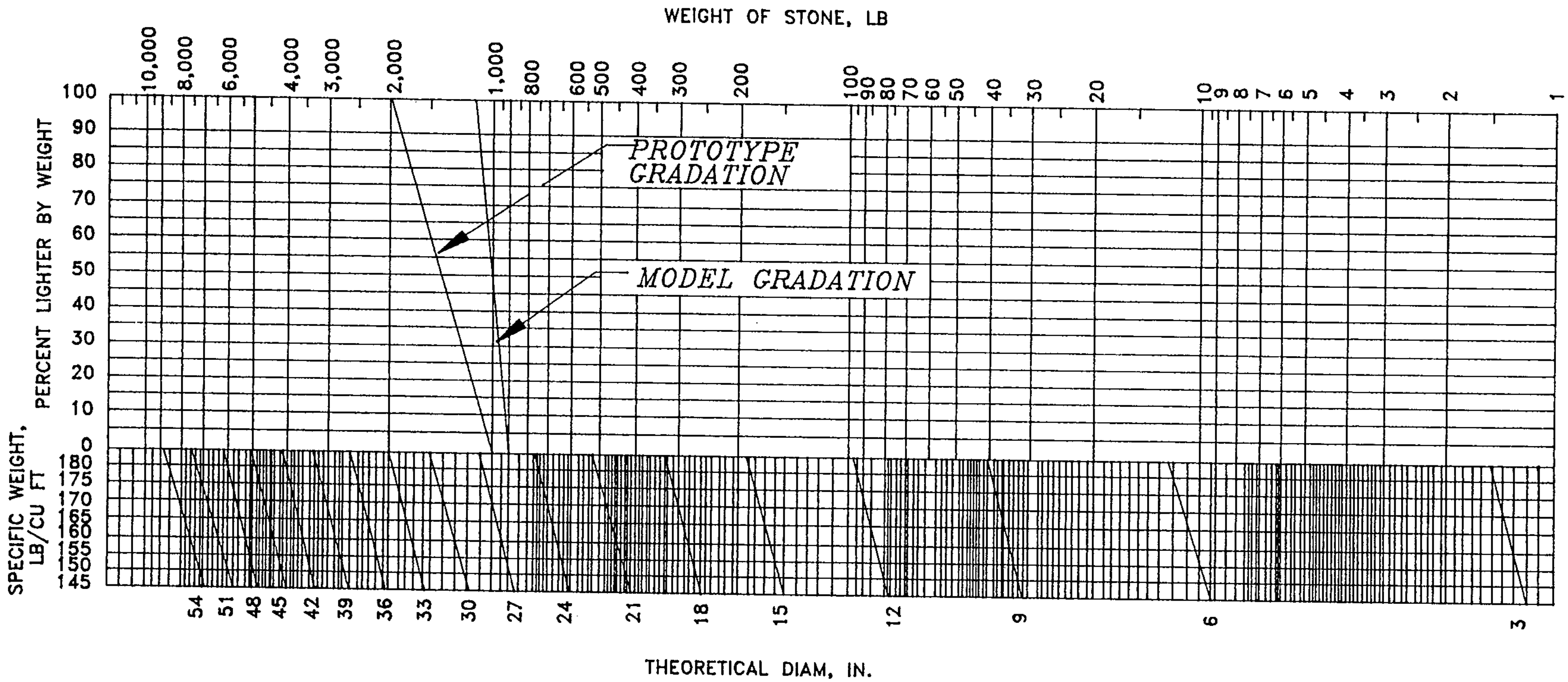


NOTE: SPECIFIC WEIGHT OF STONE 165 LB/CU FT

Note: To convert Non-SI units of measure used in this plate to SI units, multiply as shown:

Multiply	*By*	*To Obtain*
in.	*25.4*	*mm*
lb	*0.45*	*kg*
lb/cu ft	*16.02*	*kg/cu m*

RIPRAP GRADATION CURVES
15-IN.-THICK BLANKET
(CLASS A)

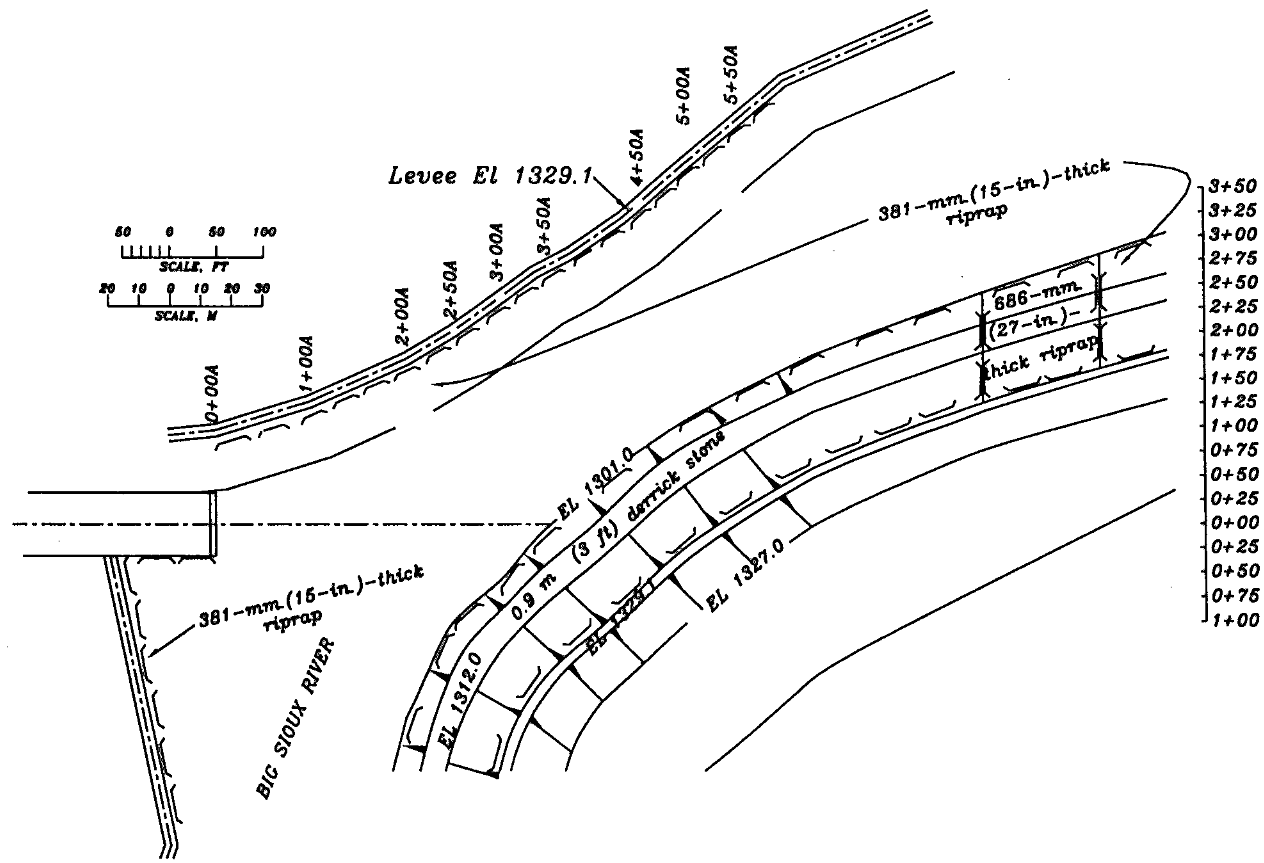


NOTE: SPECIFIC WEIGHT OF STONE 165 LB/CU FT

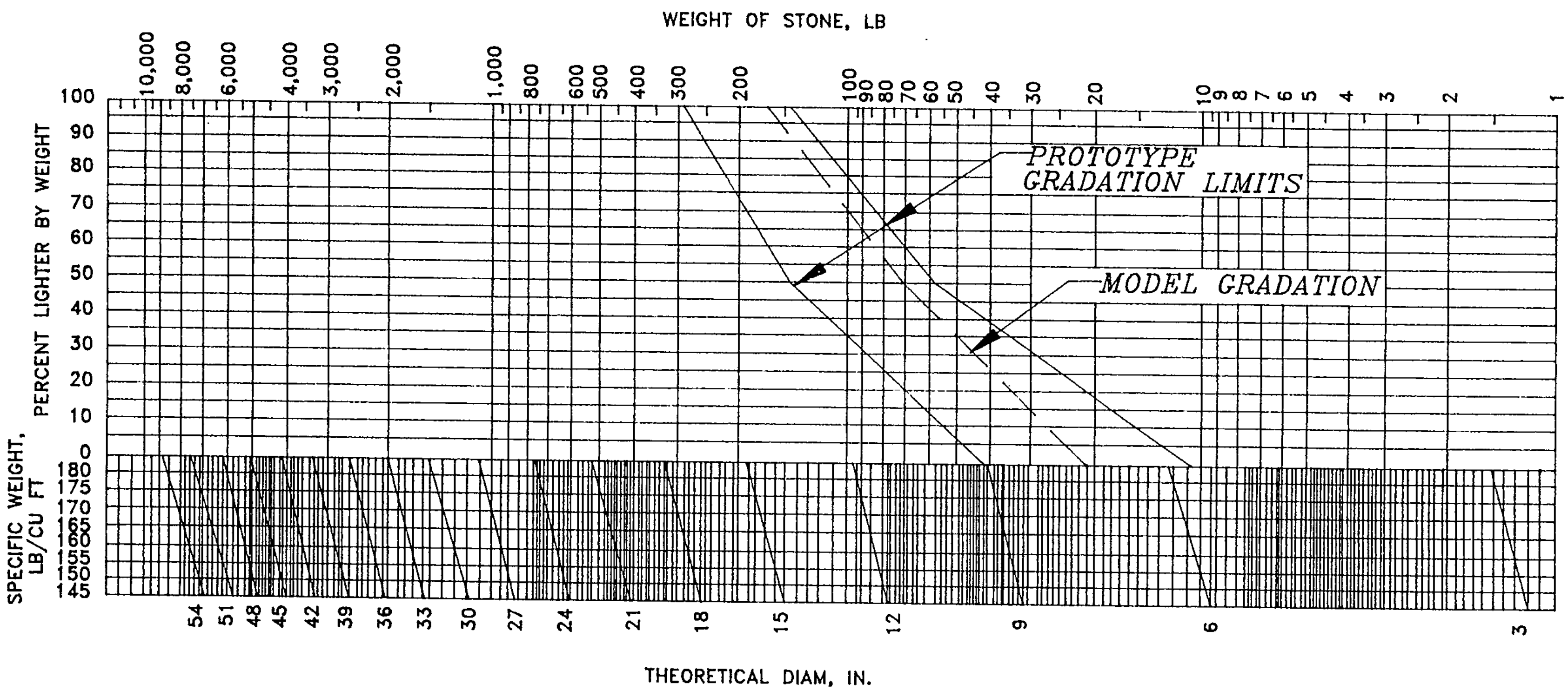
Note: *To convert Non–SI units of measure used in this plate to SI units, multiply as shown:*

Multiply	*By*	*To Obtain*
in.	*25.4*	*mm*
lb	*0.45*	*kg*
lb/cu ft	*16.02*	*kg/cu m*

RIPRAP GRADATION CURVES
3-FT DERRICK STONE
(CLASS B)



TYPE 2 RIPRAP DETAIL
REALIGNED CHANNEL



NOTE: SPECIFIC WEIGHT OF STONE 165 LB/CU FT

Note: To convert Non-SI units of measure used in this plate to SI units, multiply as shown:

Multiply	*By*	*To Obtain*
in.	*25.4*	*mm*
lb	*0.45*	*kg*
lb/cu ft	*16.02*	*kg/cu m*

RIPRAP GRADATION CURVES
27-IN.-THICK BLANKET
(CLASS C)

REPORT DOCUMENTATION PAGE

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13.ABSTRACT ***(Maximum 200 words)***

The Big Sioux River flows through Sioux Falls, located in Minnehaha County, South Dakota. A Reconnaissance Study completed in 1988 identified a Federal interest in upgrading the existing flood-control project at Sioux Falls by raising the levees. A diversion channel bypasses the 25.7-km (16-mile) loop of the Big Sioux River, avoiding the populated downstream area and a 24-m (80-ft) drop at the natural falls downstream of the downtown area. The city of Sioux Falls requested U.S. Army Corps of Engineers assistance in 1969 because of a heavy snow pack and other conditions conducive to a major flood event. The 1969 event had an estimated discharge of 840 cu m/sec (30,000 cfs) passing through the diversion channel and chute. Damage to the project occurred primarily from inadequate energy dissipation in the diversion spillway chute stilling basin and levee overtopping between the diversion dam and Western Avenue on the Big Sioux River. The Bureau of Reclamation Type III basin, designed for 672 cu m/sec (24,000 cfs), withstood an 840-cu-m/sec (30,000-cfs) discharge with a tailwater below the original design tailwater for several days with minor damage. The levee across the channel from the diversion spillway chute stilling basin suffered erosion damage and was in danger of being breached. A 1993 Feasibility Report by the Omaha District examined deepening the stilling basin, raising the stilling basin walls, and raising the levees. The design of the chute stilling basin was based on sound engineering procedures; however, the need for a model study was

(Continued)

14.SUBJECT TERMS

Channel realignment	Energy dissipation	Overtopping	Spillway	Water surface
Chute	Flood control	Riprap	Stilling basin	Wave heights
Diversion	Levees	Sioux Falls	Velocities	

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13. (Concluded).

necessary to optimize chute and stilling basin features to obtain the most economical design. The model verified that modifications to the stilling basin walls were necessary. While modifications to the stilling basin were not necessary, it was determined that channel realignment would increase energy dissipation. The following information was obtained from the model: flow characteristics and stilling basin performance, chute wall heights to prevent overtopping, downstream levee heights to prevent overtopping, riprap requirements for protection downstream of the structure, and wave heights of existing flow for design of riprap protection of the levees. The model study was used to determine the type of modifications to the basin. Serious consideration to lowering the basin was made. The model saved over $1 million by finding an alternative to construction of a new deeper basin.