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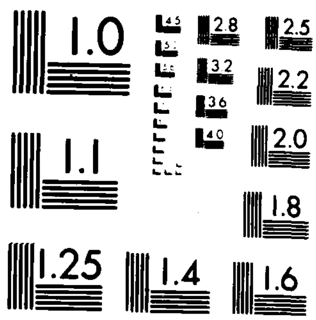
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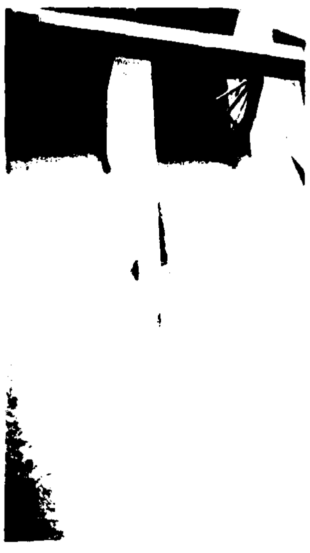

HYDRAULICS LABORATORY

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MISCELLANEOUS PAPER HL-83-4

INDIAN CREEK PUMPING STATION HYDRAULIC PROTOTYPE TESTS MANKATO, MINNESOTA

by

Richard G. McGee

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

June 1983

Final Report

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Tests were conducted to obtain data pertaining to the hydraulic performance of the facility and to verify portions of the model study results. The test program measured floor pressure fluctuations directly below the pump intakes, flow distribution in the sump entrance, and pump column vibrations. Data reduction and analysis indicated small floor pressure fluctuations, generally uniform flow distribution, and insignificant pump column vibrations. In most cases, the prototype test data compared favorably with model findings.

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PREFACE

The prototype tests described herein were conducted during April 1982 by the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the U. S. Army Engineer District, St. Paul.

Acknowledgment is made to the personnel of the St. Paul District for their assistance in the investigation. Mr. R. G. McGee, Engineer, Prototype Evaluation Branch, Hydraulic Laboratory, was test coordinator for WES. This report was prepared by Mr. McGee under the supervision of Mr. E. D. Hart, Chief of the Prototype Branch; Mr. M. B. Boyd, Chief of the Hydraulic Analysis Division; and Mr. H. B. Simmons, Chief of the Hydraulics Laboratory, WES. Instrumentation support was provided by Mr. Wallace Guy, under the supervision of Mr. L. M. Duke, Chief of the Operations Branch, Instrumentation Services. CPT A. J. Reese of the Hydraulic Analysis Division also assited with the tests.

Commander and Director of WES during the investigation and the preparation and publication of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

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CONTENTS

INDIAN CREEK PUMPING STATION
HYDRAULIC PROTOTYPE TESTS
MANKATO, MINNESOTA

PART I: INTRODUCTION

Pertinent Features of the Project

1. The Indian Creek storm-water pumping station is located in Mankato, Minnesota, at the junction of Indian Creek with the Minnesota River. The pumping station is of the wet-pit (sump) type and employs four vertical shaft pumps providing a total pumping capacity of 136,000 gpm. The project also includes facilities for gravity flow. The pumping station is used for pumping storm-water runoff only. Design details of the pumping station are shown in Plate 1.

2. Prior to its construction, the Waterways Experiment Station (WES) conducted a model study to evaluate the characteristics of pumped and gravity flows in the original design of the pumping station.* The study resulted in the development of modifications required for improving the distribution of flow to the pump intakes and gravity flow outlets.

Purpose and Scope of Study

Purpose

3. Prototype tests were conducted in April 1982 to obtain data pertaining to the hydraulic performance and operating condition of the facility. The procedures, equipment, and results of the tests are discussed herein.

Objectives

4. The overall objective of the tests was to obtain prototype

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* Bobby P. Fletcher. 1978 (Jun). "Indian Creek Pumping Station; Hydraulic Model Investigation, Technical Report H-78-8, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

data for comparison with model study data. The test data are used to verify certain portions of the model study results and provide a practical evaluation of the final design.

5. Primary objectives of these tests were to:

   a. Measure the floor pressure fluctuations directly below the vertical axis of the pump columns.

   b. Determine the flow distribution at the pump intakes by measuring approach velocities across each sump.

6. Secondary objectives were to:

   a. Determine any significant vibration of the pump column due to adverse flow conditions.

   b. Calibrate an elbow meter for evaluation as a method of measuring pump discharge.

Scope

7. On 15-16 April 1982, thirteen tests were conducted at Indian Creek Pumping Station. Individual tests varied with respect to quantity and scope of data collected. A breakdown of the tests with the type of data collected is presented in Table 1.

PART II: TEST FACILITIES AND EQUIPMENT

8. The locations of the test instrumentation described herein are shown in Plates 2 and 3. The specifics of each transducer are listed in Table 2.

Pressure Transducers

9. Floor pressure fluctuations for each sump were measured with 25 psia strain gage pressure transducers mounted in the sump floor directly below the vertical axis of each pump intake. The locations of the floor pressure cells (F1, F2, F3, and F4) are shown in Plate 2. A 25 psia pressure transducer was also used to measure pump chamber water surface elevation. These gages (W1, W2, W3, and W4) were mounted in the training wall of each sump. Locations of the wall gages are also shown in Plate 2.

Current Velocity Meters

10. Approach velocites across each sump were measured with calibrated one- and two-dimensional electromagnetic current meters.* A cup-type turbine current meter was used as a back-up in a number of tests. The velocities were read with direct readout indicators and were manually recorded.

Accelerometers

11. A triaxial pod of ± 20-g accelerometers was mounted at the center of the upstream face of pump column no. 1 at approximately elevation 768** (see Plate 3). Accelerometers AL, AT, and AV measured

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* Mirsh-McBurney electromagnetic current meters.

** All elevations cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).

accelerations in the longitudinal (upstream/downstream) direction, the transverse (perpendicular to flow) direction, and the vertical direction.

Piezometers

12. Piezometer rings were installed at elevation 764.60 on all four pump columns to measure pump column pressure for discharge determination. The piezometer rings consisted of four 1/4-inch National Pipe Thread (NPT) ports spaced at 90° around the column (See Plate 3) interconnected with 1/8-inch inside diameter tygon tubing. A single 1/8-inch inside diameter pressure line led from each piezometer ring to 50 psia pressure transducers located in the pump chamber.

13. Two 1/4-inch NPT ports at elevation 766.23 were used to conduct elbow meter calibrations on pump no. 1. These ports were positioned at diametrically opposite locations, one on the inside radius of the elbow, the other on the outer face of the pump column (see Plate 3). A differential U-tube manometer was connected to the pump column elbow by 1/8-inch inside diameter pressure lines. The manometer indicator fluid used was Meriam No. 3 Red Fluid with a specific gravity of 2.95.

Recording Equipment

14. The signals from the pressure transducers and accelerometers were amplified and recorded with a 14-channel magnetic tape data recorder. Data were also reproduced on a 12-inch chart oscillograph for visual field inspection and for reference during the data reduction. All of the recording equipment was located in the superstructure above the pump chamber (see Plate 2). Embedded electrical conduit was used for passing the transducer cables from the pressure cell locations in the floor and training walls of the sumps to the recording area.

PART III: TEST CONDITIONS AND PROCEDURES

Conditions

15. When the downstream river elevation is below flood stage the three 7-ft square conduits convey gravity flows to the river. Normal operating conditions during potential flood periods (when the river exceeds elevation 761) involve closing the sluice gates on the gravity flow outlets, opening the gates to the pump chamber, activating the pumps, and pumping until the sump water level reaches minimum sump elevation (el 757). In the model study a constant sump water surface elevation was maintained along with the above conditions during the entire duration of each test. However, due to insufficient storm-water runoff, a constant water surface elevation was impossible to maintain during the prototype tests. The rapid drawdown in water surface elevation under normal operating conditions did not provide a sufficient amount of time to adequately record the data.

16. Because a constant water level was essential to proper data collection, the tests were conducted under alternative operating conditions. The gates to the gravity flow outlets were opened allowing water to circulate from the downstream river into the pumping plant. This provided a maximum sump elevation equal to the river stage (el. 761). Also, by manipulating these outlet gates the desired sump water surface elevation could be set and maintained.

17. A 61-in bell diameter pump intake, as originally designed, was used for all pumps in the model study. In the prototype, however, a 90-in diameter umbrella (see Plate 3) had been attached directly to each of the pump intakes.

Procedures

18. Test procedures were generally the same for all tests and consisted of the following:

a. Record test number, date, time, and conditions.

b. Record step calibrations.

c. Activate pumps; allow flow to stabilize.

d. Record data on tape, oscillogram, and data sheets.

e. Record step calibrations.

PART IV: TEST RESULTS AND ANALYSIS

Discharge Measurements

19. Pump discharge was determined using rating curves provided by the manufacturer based on total dynamic head (TDH). This curve is shown by Plate 4. Pump column pressure measurements (refer to paragraph 12) were recorded and converted to TDH in order to calculate discharge. The measured discharges for the prototype tests ranged from 16 to 22 percent higher than those of the model study which were held constant at 34,000 gpm.

Elbow Meter Calibration

20. Calibration of an elbow meter for evaluation as a method of discharge determination was a secondary test objective. Three tests utilizing the elbow meter were conducted at Indian Creek. Unfortunately, three tests of this nature did not provide a sufficient range of data for proper evaluation. Therefore, no elbow meter rating curve is included in this report. The data, as listed below, will be retained for future reference.

Test No.	Differential Pressure (PSID)	Discharge (GPM)
4	1.78	41,300
5	2.16	41,600
9	1.92	39,500

Floor Pressure Fluctuation Measurements

21. Twelve tests measuring floor pressure fluctuations at the pump intakes were conducted. Table 3 gives a tabulation of average and maximum peak-to-peak fluctuations for each sump. This maximum value

is characterized by high magnitude and low frequency; an indication of swirl at the pump intakes. However, this phenomenon occurred only randomly and was not present in all tests. Typical time history plots of maximum pressure fluctuations are given in Plate 5.

22. Overall, pressure fluctuations indicated little or no rotational flow tendencies. The average pressure fluctuation values ranged from 0.2 to 0.8 feet*. The largest maximum was 4.9 feet and occurred in sump 4, test 6 and sump 2, test 9. Test 6 was performed with only pump 4 operating, a water level of 756.9, and a discharge of 39,500 gpm. Test 9 was conducted with all pumps operating. Sump 2 had a water level of 757.1 and a discharge of 39,700 gpm. Other maximums occurred in tests 3, 4, 8, and 9.

Velocity Measurements

23. Approach velocities were measured at two locations (one upstream and one downstream of the vortex suppressor) in each sump to determine the velocity profiles. These locations are shown in Plate 2. In some tests velocities were measured horizontally one-foot above the sump floor (el. 751) and in others over the entire cross-section of flow. From these data, two types of velocity profiles were constructed to help visualize the flow characteristics in each sump. The first, as presented in plates 6 through 15, shows the horizontal velocity profiles occuring one foot above the floor of each sump. These profiles can be readily compared with those illustrated in the model study report. The second type, as shown in plates 16 through 22, are velocity "isovels" depicting flow patterns over the entire depth of flow. These data were taken only in tests 6, 8, 9, 10, 12, and 13. The velocities were measured in one sump only, except during test 13.

24. Because of the higher discharges, prototype velocities were higher than model study velocities. Inflow during the prototype tests entered the intake chamber through the gravity flow outlets. Flow was

---

* Pressure fluctuations given in feet of water.

then forced to turn 180 degrees into the sump chambers. This caused flow separation along the right wall (looking upstream) of the approaches at or near the pier noses. However, because of the relatively low velocities and the large length to width ratio of the sump chambers, the flow distribution tended to equalize at the measurement locations. This is evident in the velocity profiles of plates 6 through 22. Only occasional stage A and stage B vortexes (see Figure 1) developed in the area of the pump intake.

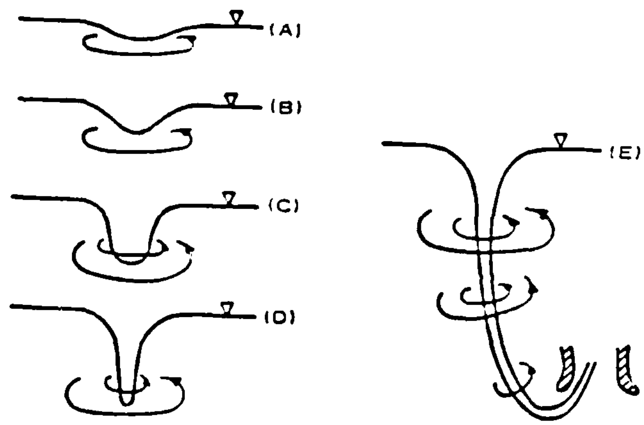


Figure 1. Stages in development of air-entraining vortex

25. The accuracy of the velocity measurements was checked by comparing the computed discharge of the average of the measured point velocities over the entire depth of flow (i.e., tests 6, 8, 9, 10, 12, and 13) with the discharge determined using the rating curves. An average difference of $\pm$ 2.4 percent between the two methods indicates an accuracy within acceptable limits.

Pump Vibration

26. As stated in paragraph 6, a secondary objective of these tests was to determine if any significant vibration of the pump column occurred due to adverse flow conditions established in the approach chambers such as flow disruption caused by excess debris on the trash racks or other unanticipated flow conditions. Five tests were conducted measuring accelerations on pump column 1. Of these tests only test 11 was performed under adverse flow conditions. For test 11, the water level was allowed to fall below the minimum pumping level (el. 757) to a level below the intake of the pump (approximately el. 752).

27. Vibrations of the pump column were very small and considered to be insignificant during all tests. The maximum peak-to-peak amplitudes were recorded by the accelerometers in the longitudinal and transverse directions during test 11 when the water level reached the elevation of the pump intake. These maximum recordings and corresponding displacements were as follows:

Direction	Peak-to-Peak Amplitude, g's	Frequency Hz	Displacement* inches
Vertical	0.006	40	--**
Longitudinal	0.800	30	0.0086
Transverse	0.575	30	0.0062

* Displacements estimated by the sinusoidal equation $d = 386 \times \text{acceleration}/(2\pi \text{freq})^2$.

** Data omitted where values were insignificant.

Plate 23 shows an example acceleration time history and Table 4 gives a complete tabulation of accelerations, frequencies, and displacements for each test.

PART V: CONCLUSIONS

28. The following determinations resulted from field observations and analysis of the reduced prototype data.

- a. Velocities measured in the approach indicated generally uniform flow distribution despite the fact flow was circulated from the river to the intake chamber through the gravity flow outlets.
- b. Pressure fluctuations on the sump floor were small implying little or no rotational flow.
- c. Only occasional stage A and stage B vortexes developed in the area of the pump intake.
- d. Pump column vibrations were considered insignificant.
- e. Although conditions for the model and prototype tests differed somewhat, the prototype test data compared favorably with model findings.

Table 1

Test Schedule for Indian Creek Pumping Station

Prototype Test, 15-16 April 1982

Test No.	Pump No.	Data Collected*
1	4	A, B, C, E
2	3, 4	A, B, C, E
3	2, 3, 4	A, B, C, E
4	1, 2, 3, 4	A, B, C, E, F, G
5	1	A, B, C, E, F, G
6	4	A, B, C, D, E
7	3, 4	A, B, C, E
8	2, 3, 4	A, B, C, D, E
9	1, 2, 3, 4	A, B, C, D, E, F, G
10	1	A, B, C, D, E, F
11	1	F
12	4	A, B, D, E
13	3, 4	A, B, D, E

* Data Collected:

A = Pump chamber water surface elevation
B = Floor pressure fluctuations
C = Approach velocities measured 1-foot above sump floor.
D = Approach velocities measured over entire depth of flow.
E = Pump column pressure to determine discharge.
F = Pump column vibration (Pump 1 only).
G = Elbow meter calibration (Pump 1 only).

Table 2

Instrumentation

Instrument		Instrument Location*		Cable	
Code	Range	Description	Elev.	Length, ft	Parameter
F1	25 psia	Sump floor	750.0	110	Pressure fluctuation
F2	25 psia	Sump floor	750.0	90	Pressure fluctuation
F3	25 psia	Sump floor	750.0	75	Pressure fluctuation
F4	25 psia	Sump floor	750.0	54	Pressure fluctuation
W1	25 psia	Training wall	753.0	100	Sump water level
W2	25 psia	Training wall	753.0	100	Sump water level
W3	25 psia	Training wall	753.0	75	Sump water level
W4	25 psia	Training wall	753.0	75	Sump water level
P1	50 psia	Piezometer	764.6	76	Pump column pressure
P2	50 psia	Piezometer	764.6	50	Pump column pressure
P3	50 psia	Piezometer	764.6	50	Pump column pressure
P4	50 psia	Piezometer	764.6	50	Pump column pressure
AL	± 20 g's	Pump column	768.0	50	Longitudinal vibration
AT	± 20 g's	Pump column	768.0	50	Transverse vibration
AV	± 20 g's	Pump column	768.0	50	Vertical vibration
EL	2.5 psid	Piezometer	766.23	None	Pressure differential (elbow meter)

* See Plates 2 and 3

Table 3

Pressure Fluctuations at Pump Intakes

Test No.	Item	Pump No. 1	2	3	4
1	Sump El, ft	X	X	X	760.7
	Discharge, gpm				41,100
	Pressure fluctuation*				0.3
	Maximum**				--†
2	Sump El, ft	X	X	760.7	760.6
	Discharge, gpm			41,200	41,000
	Pressure fluctuation*			0.2	0.3
	Maximum**			--†	--†
3	Sump, El, ft	X	760.6	760.6	761.0
	Discharge, gpm		41,600	41,300	41,300
	Pressure fluctuation*		0.3	0.3	0.4
	Maximum**		1.3	--†	1.1
4	Sump, El, ft	760.6	760.5	760.6	761.0
	Discharge, gpm	41,300	41,650	41,400	††
	Pressure fluctuation*	0.5	0.3	0.4	0.3
	Maximum**	0.8	--†	--†	1.0
5	Sump El, ft	760.8	X	X	X
	Discharge, gpm	41,600			
	Pressure fluctuation*	0.5			
	Maximum**	--†			
6	Sump El, ft	X	X	X	756.9
	Discharge, gpm				39,500
	Pressure fluctuation*				0.7
	Maximum**				4.9
7	Sump El, ft	X	X	756.7	756.6
	Discharge, gpm			39,300	39,300
	Pressure fluctuation*			0.2	0.3
	Maximum**			--†	--†

(Continued)

Note: X = pump not operating
gpm = gallons per minute
* Pressure fluctuations given in feet of water (pk-pk)
** Maximum = significant pressure fluctuation (see Plate 5)
† Data insignificant
†† No data taken

(Sheet 1 of 2)

Table 3 (Concluded)

Test No.	Item	Pump No. 1	2	3	4
8	Sump El, ft	X	756.9	756.9	756.7
	Discharge, gpm		39,500	39,400	39,400
	Pressure fluctuation*		0.4	0.4	0.3
	Maximum**		--†	--†	1.3
9	Sump El, ft	757.1	757.1	757.2	756.9
	Discharge, gpm	39,500	39,700	39,500	††
	Pressure fluctuation*	0.8	0.4	0.7	0.3
	Maximum**	--†	4.9	1.5	2.0
10	Sump El, ft	756.8	X	X	X
	Discharge, gpm	††			
	Pressure fluctuation*	0.4			
	Maximum**	--†			
12	Sump El, ft	X	X	X	760.8
	Discharge, gpm				41,600
	Pressure fluctuation*				0.2
	Maximum**				--†
13	Sump El, ft	X	X	760.9	760.8
	Discharge, gpm			41,300	41,550
	Pressure fluctuation*			0.2	0.2
	Maximum**			--†	--†

(Sheet 2 of 2)

Table 4

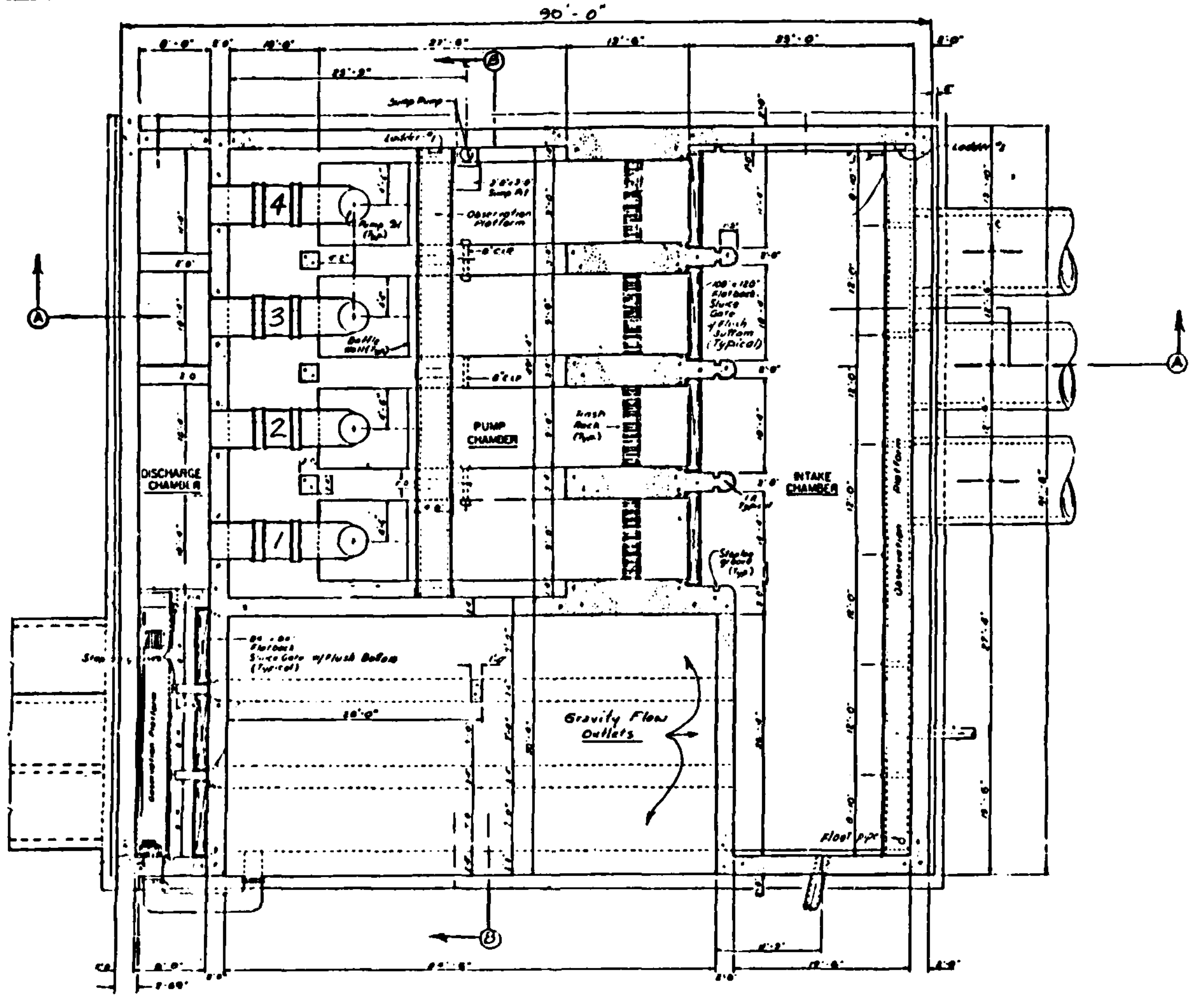
Pump Column Vibration

Test No.	Sump El, ft	Item*	Transducer Location		
			Vertical	Longitudinal	Transverse
4	760.6	Max, g's	0.035	0.058	0.026
		Min, g's	-0.027	-0.045	-0.027
		P/P, g's	0.061	0.100	0.051
		Freg, Hz	30	30	30
		Displ, in	0.0007	0.0011	0.0006
5	760.8	Max, g's	0.032	0.087	0.060
		Min, g's	-0.043	-0.062	-0.041
		P/P, g's	0.061	0.126	0.078
		Freq, Hz	30	30	30
		Displ, in	0.0007	0.0014	0.0008
9	757.1	Max, g's	0.026	0.101	0.055
		Min, g's	-0.039	-0.118	-0.049
		P/P, g's	0.061	0.220	0.198
		Freq, Hz	30	40	40
		Displ, in	0.0007	0.0013	0.0012
10	756.8	Max, g's	0.029	0.115	0.098
		Min, g's	-0.078	-0.100	-0.048
		P/P, g's	0.093	0.203	0.126
		Freq, Hz	30	40	40
		Displ, in	0.0010	0.0012	0.0008
11	752	Max, g's	--**	0.419	0.257
		Min, g's	--**	-0.457	-0.341
		P/P, g's	0.006	0.800	0.575
		Freq, Hz	40	30	30
		Displ, in	--**	0.0086	0.0062

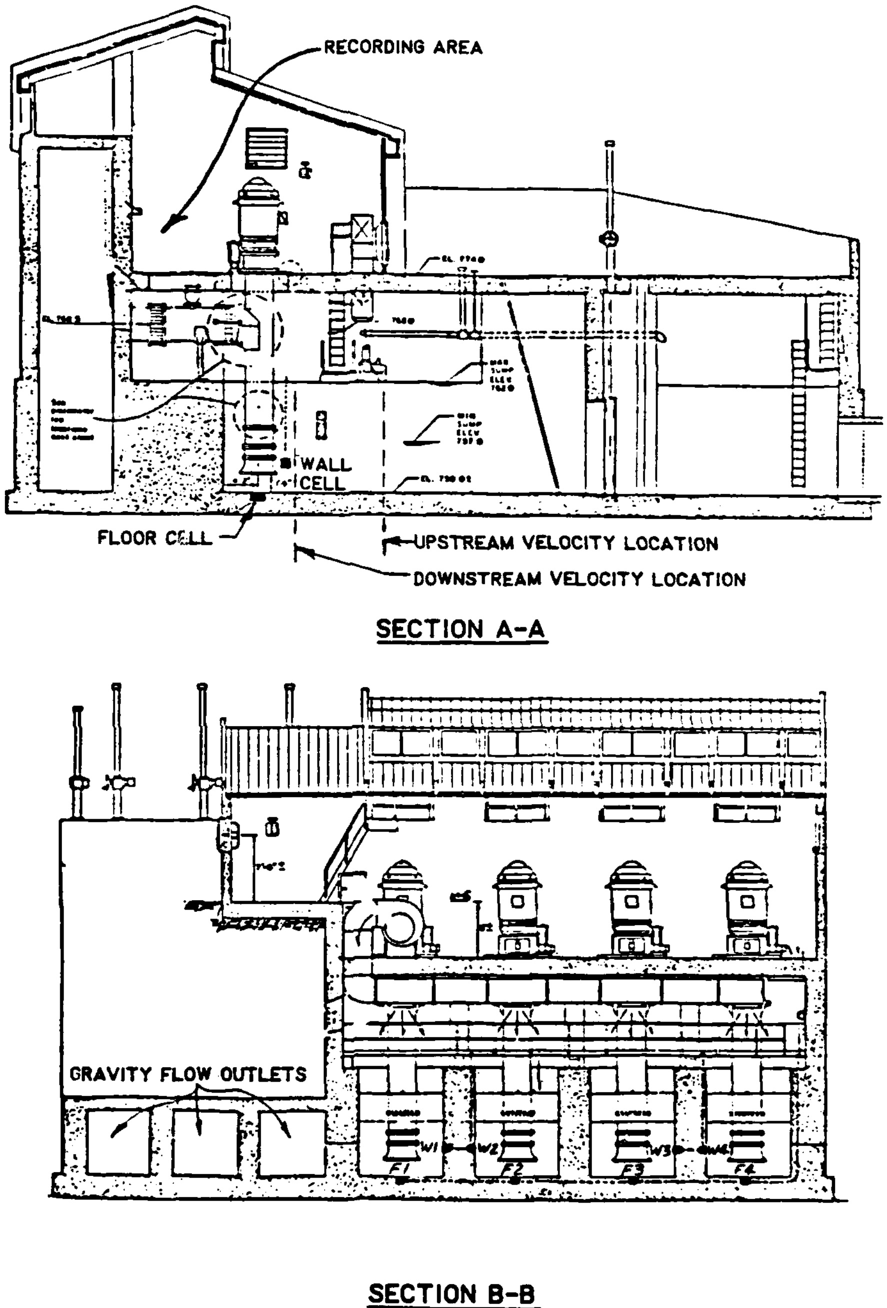
* Max, g's = greatest instantaneous acceleration in (+) direction.
Min, g's = greatest instantaneous acceleration in (-) direction.
P/P, g's = greatest instantaneous peak-peak acceleration.
Freq, Hz = predominant frequency of oscillation used.
Displ, in = peak-to-peak sinusoidal displacement =

$$\frac{386 \times \text{acceleration}}{(2\pi \times \text{frequency})^2}$$

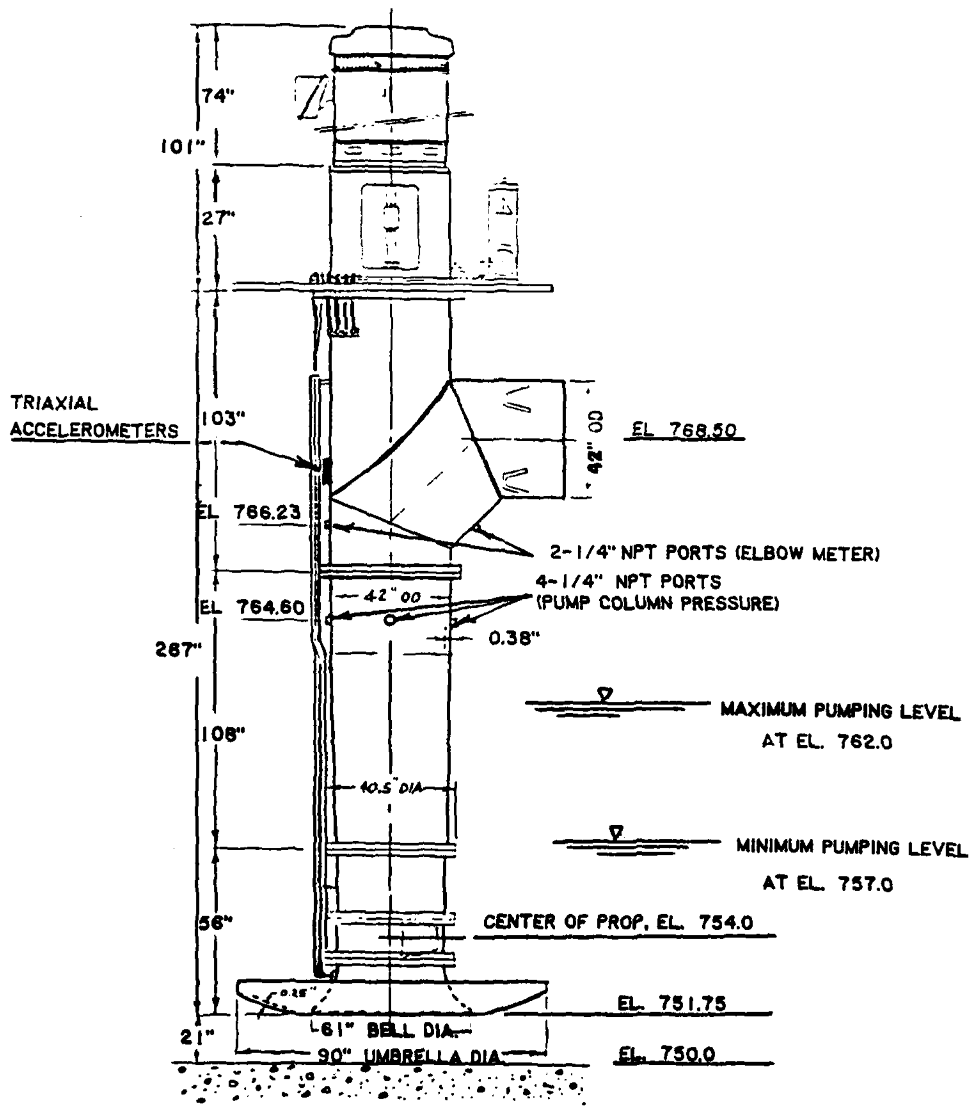
** Data ommitted where recorded measurements were insignificant.



PLAN VIEW OF
INDIAN CREEK PUMPING STATION

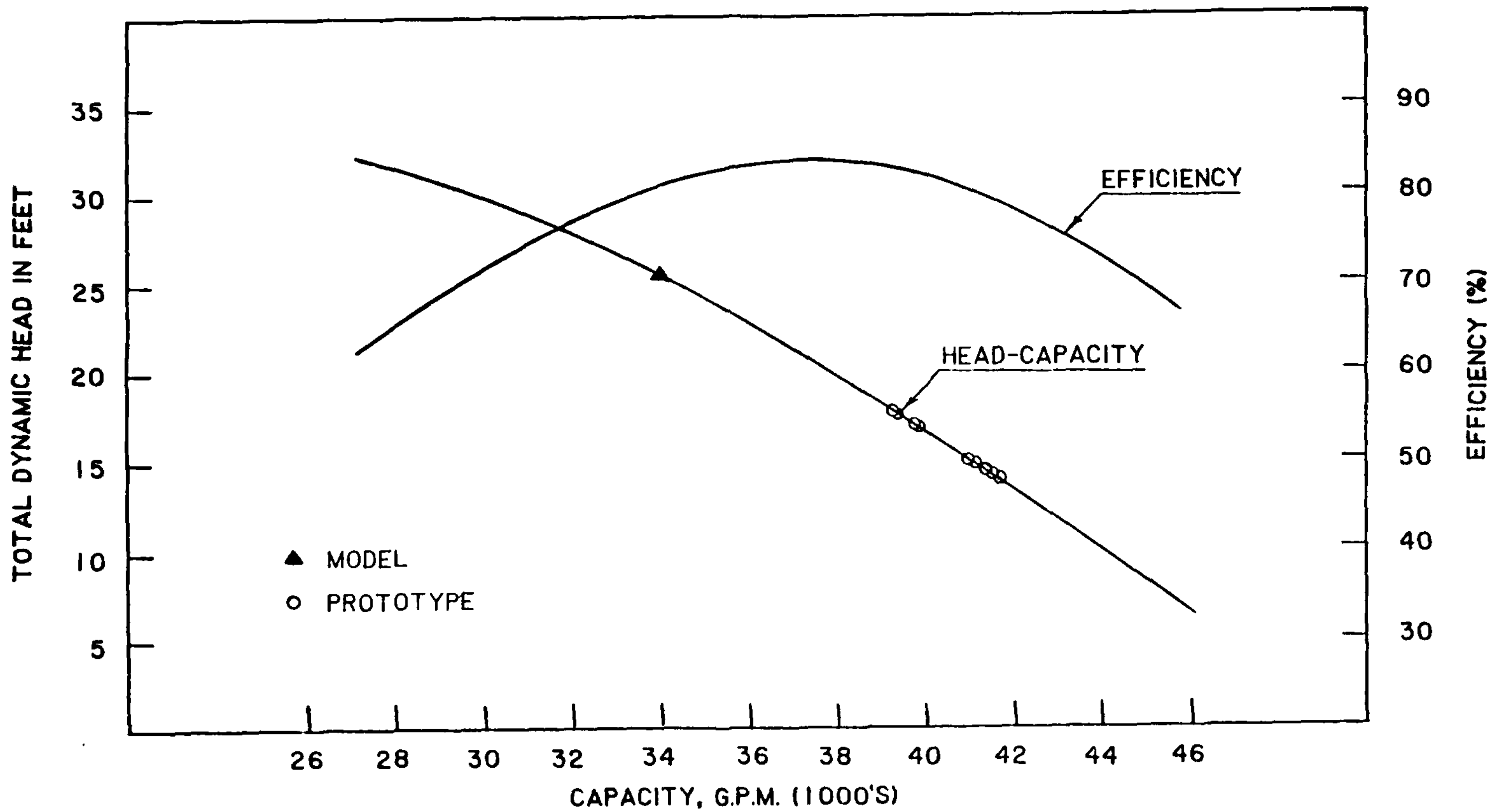


GENERAL FEATURES OF
INDIAN CREEK PUMPING STATION



PUMP DIMENSIONS

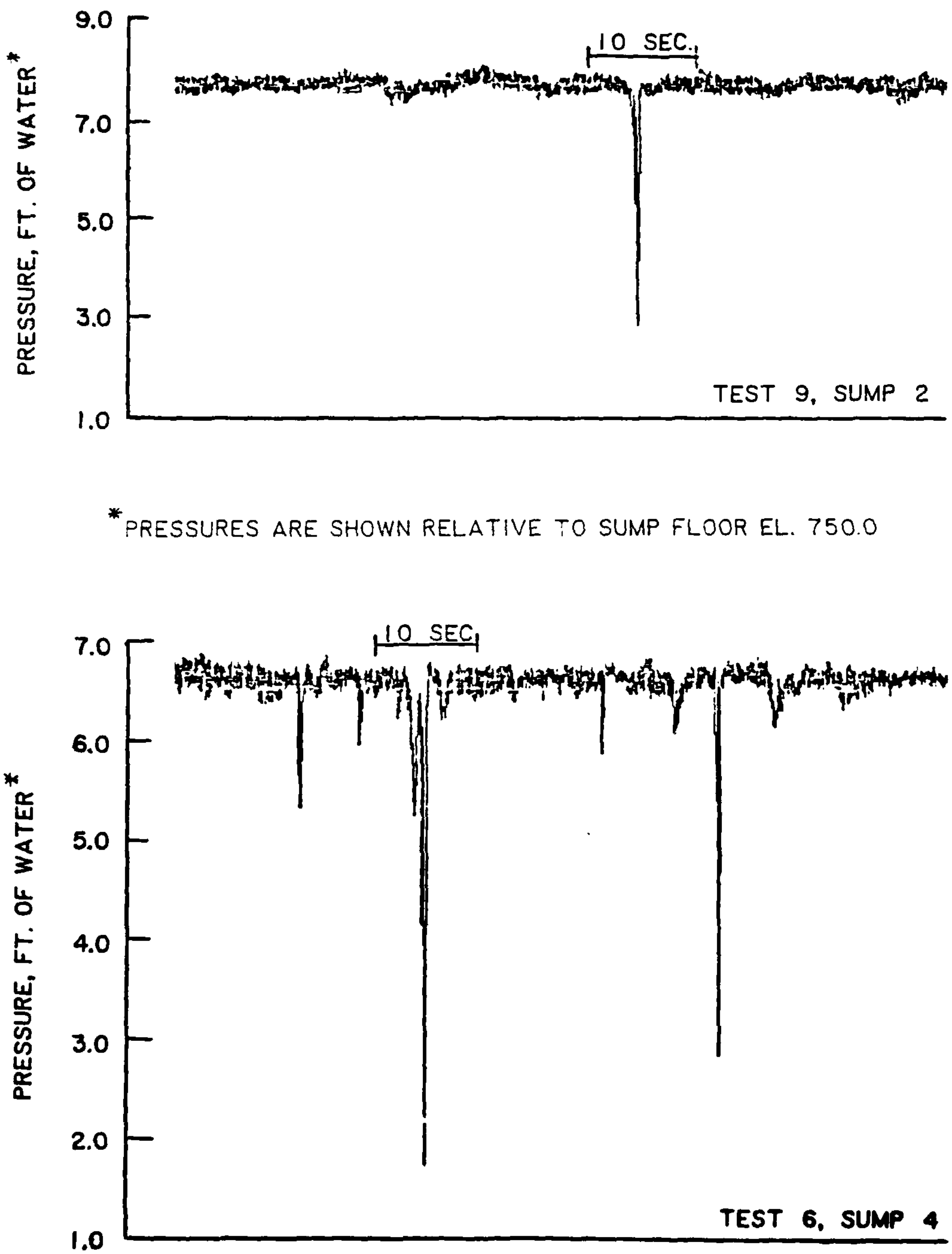
PLATE 3



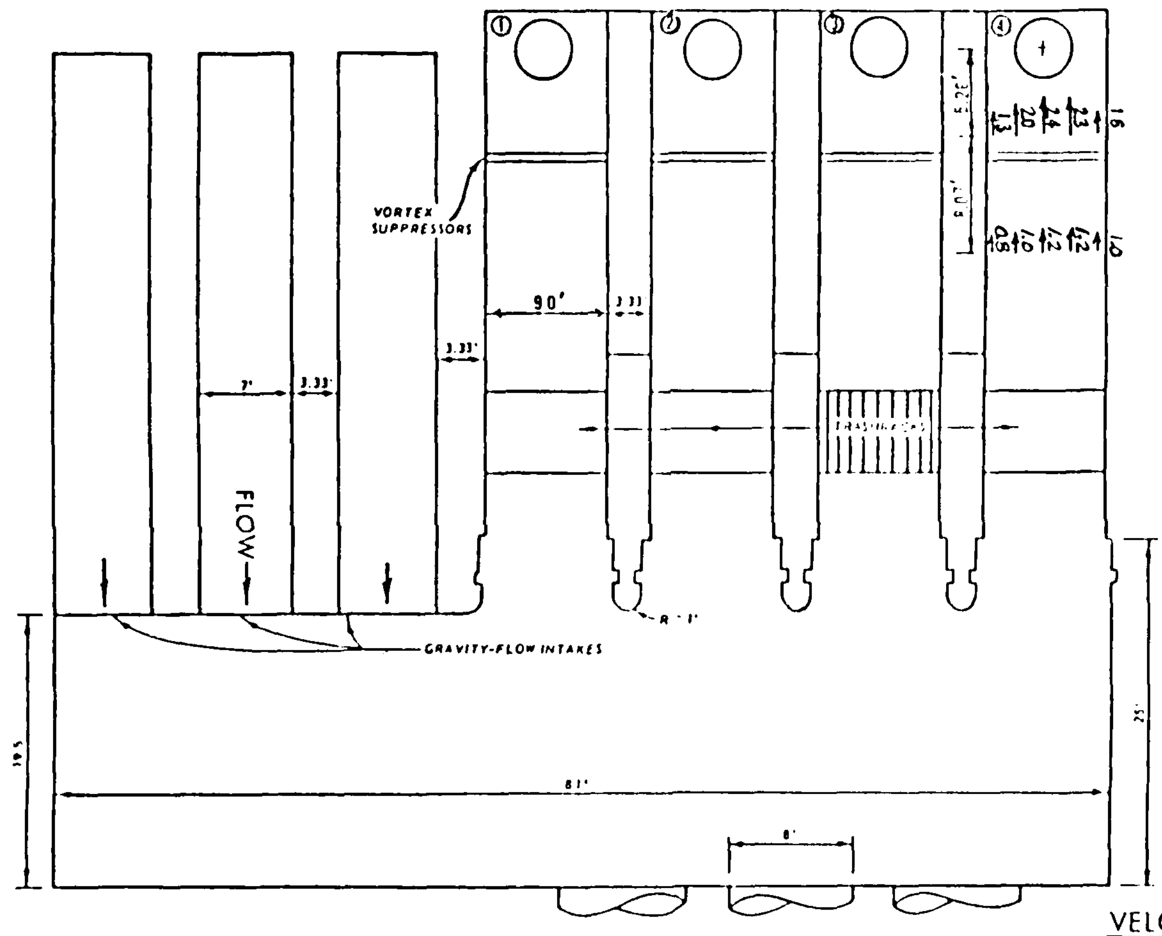
PUMP DISCHARGE RATING CURVE

(PROVIDE BY MANUFACTURER)

PLATE 4



MAXIMUM PRESSURE FLUCTUATIONS



VELOCITY PROFILES

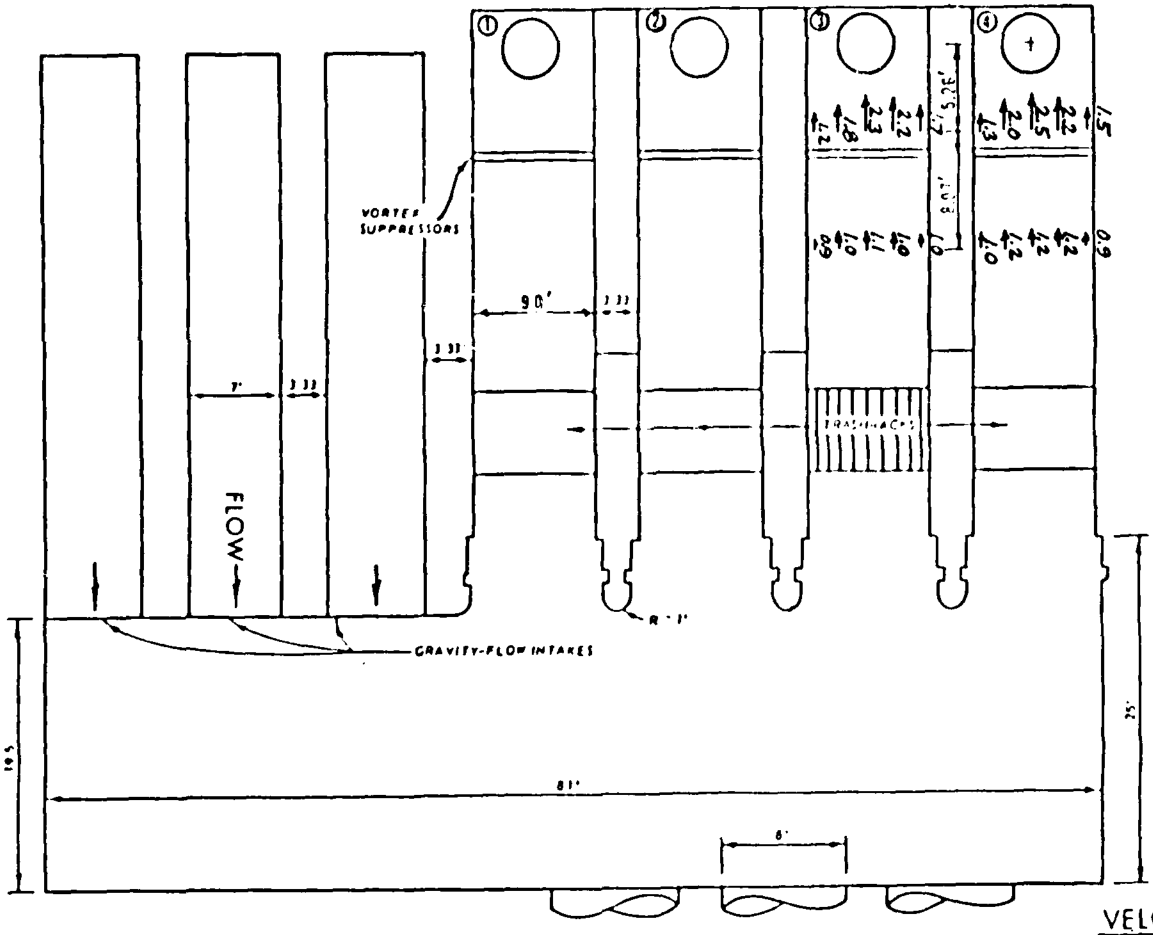
TEST NO. 1

SUMP ELEV. 761

PUMP 4

VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM

PLATE 6



VELOCITY PROFILES

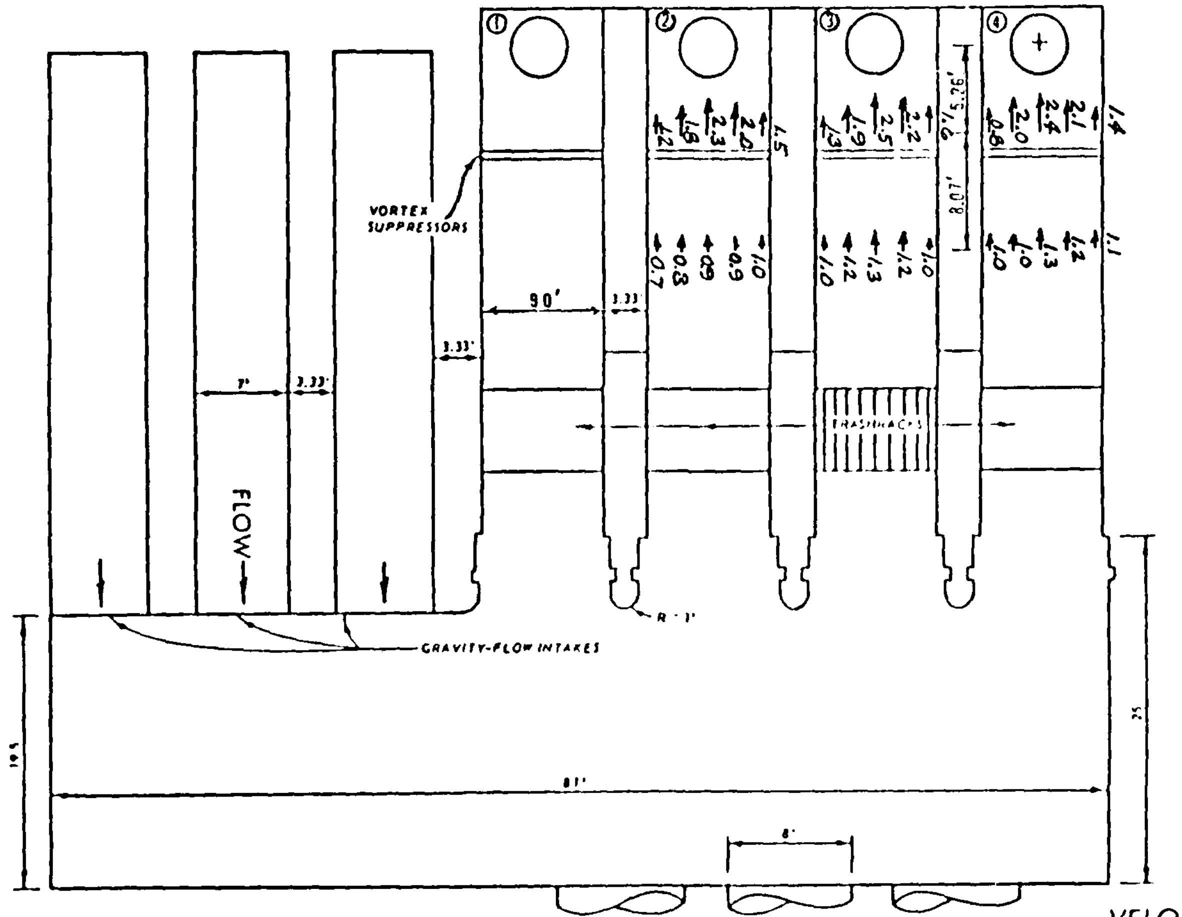
TEST NO. 2

SUMP ELEV. 761

PUMP 3,4

VELOCITIES IN FEET PER SECOND

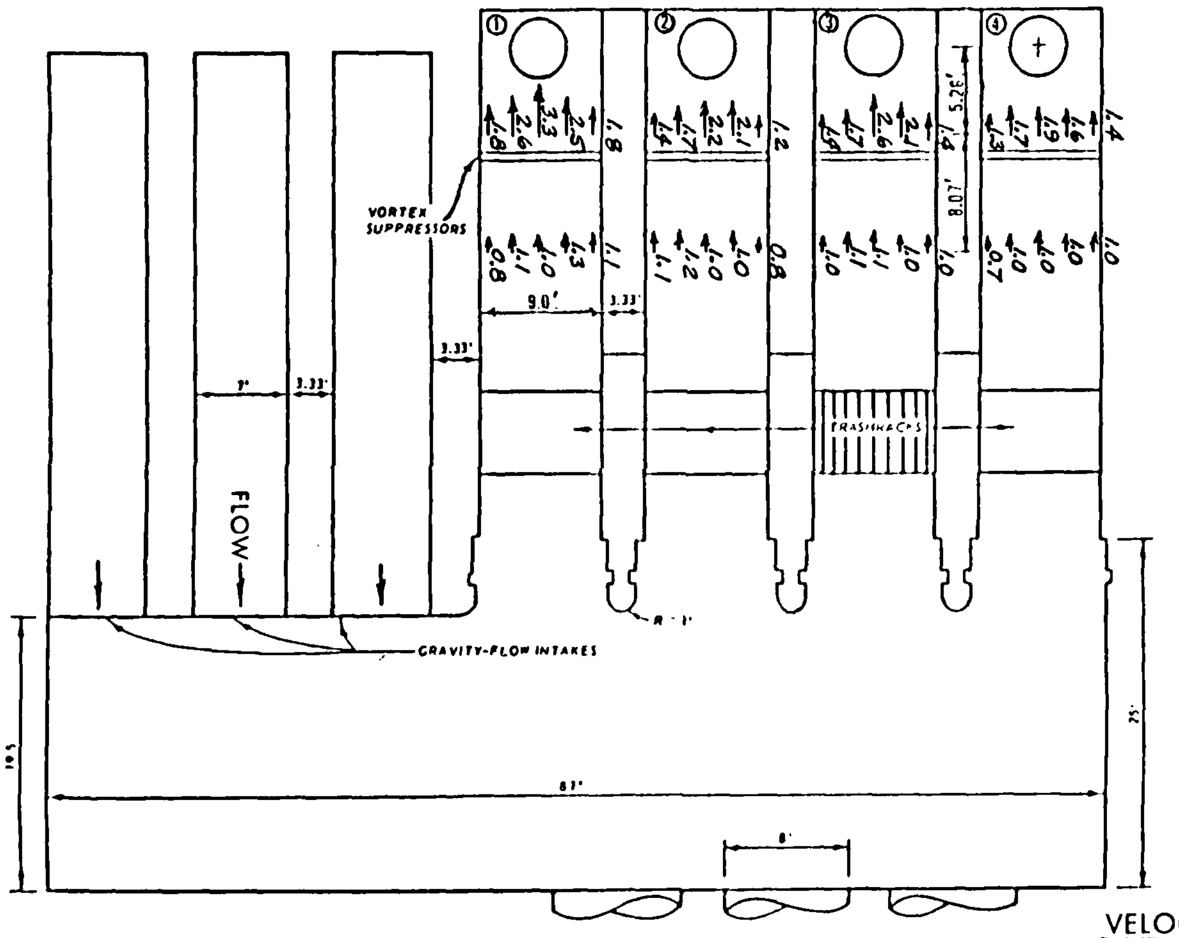
MEASURED 1 FT ABOVE BOTTOM



VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM

VELOCITY PROFILES
TEST NO. 3
SUMP ELEV. 761
PUMP 2,3,4

PLATE 8



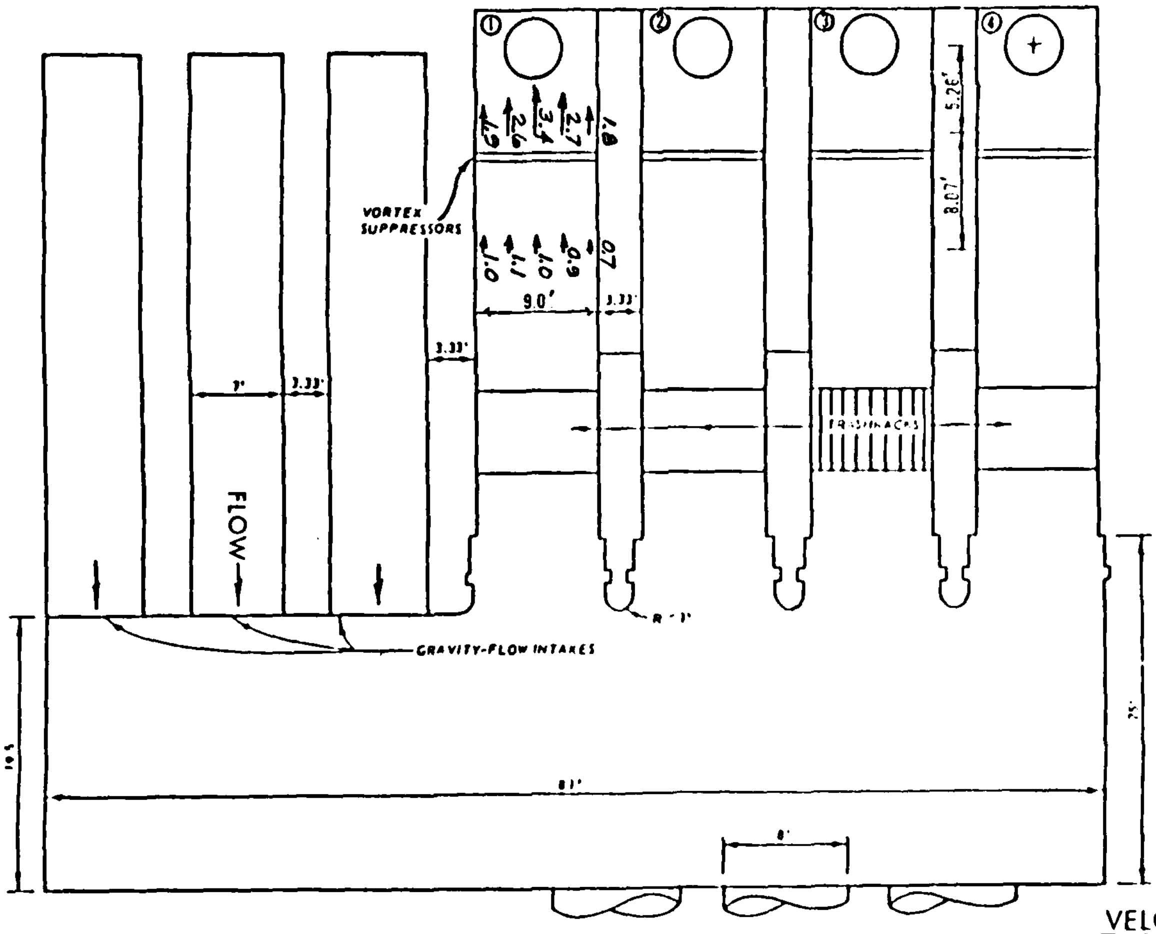
VELOCITY PROFILES

TEST NO. 4

SUMP ELEV. 761

PUMP 1,2,3,4

VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM



VELOCITY PROFILES

TEST NO. 5

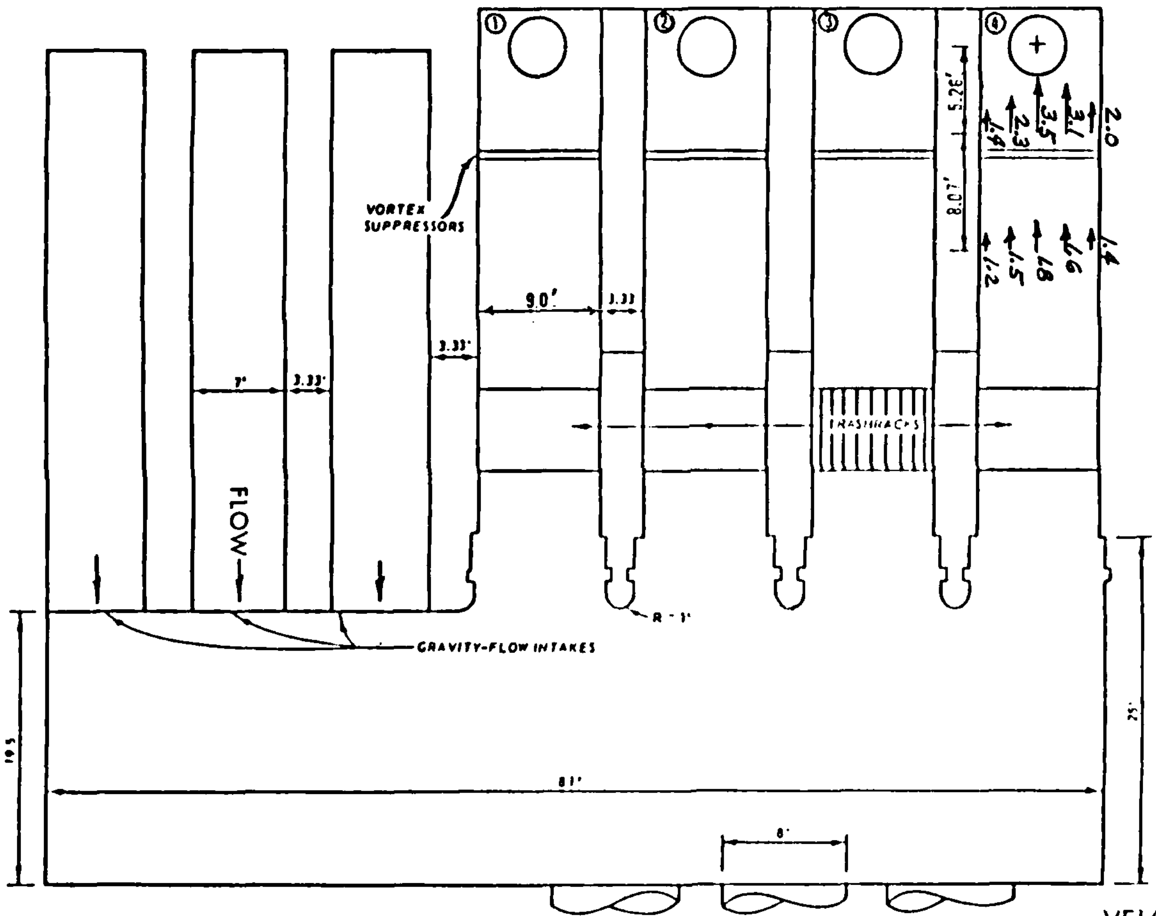
SUMP ELEV. 761

PUMP 1

VELOCITIES IN FEET PER SECOND

MEASURED 1 FT ABOVE BOTTOM

PLATE 10



VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM

VELOCITY PROFILES
TEST NO. 6
SUMP ELEV. 757
PUMP 4

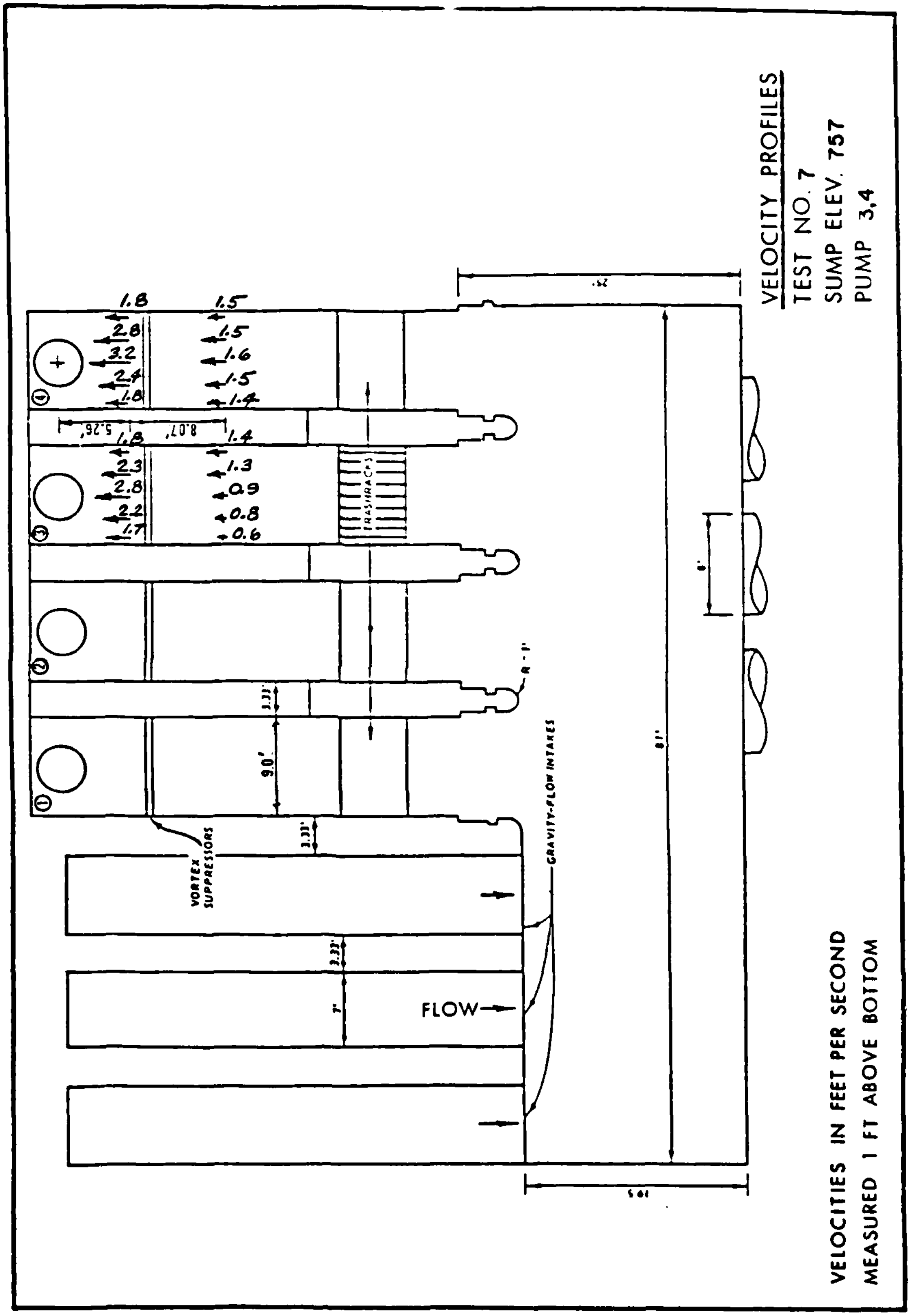
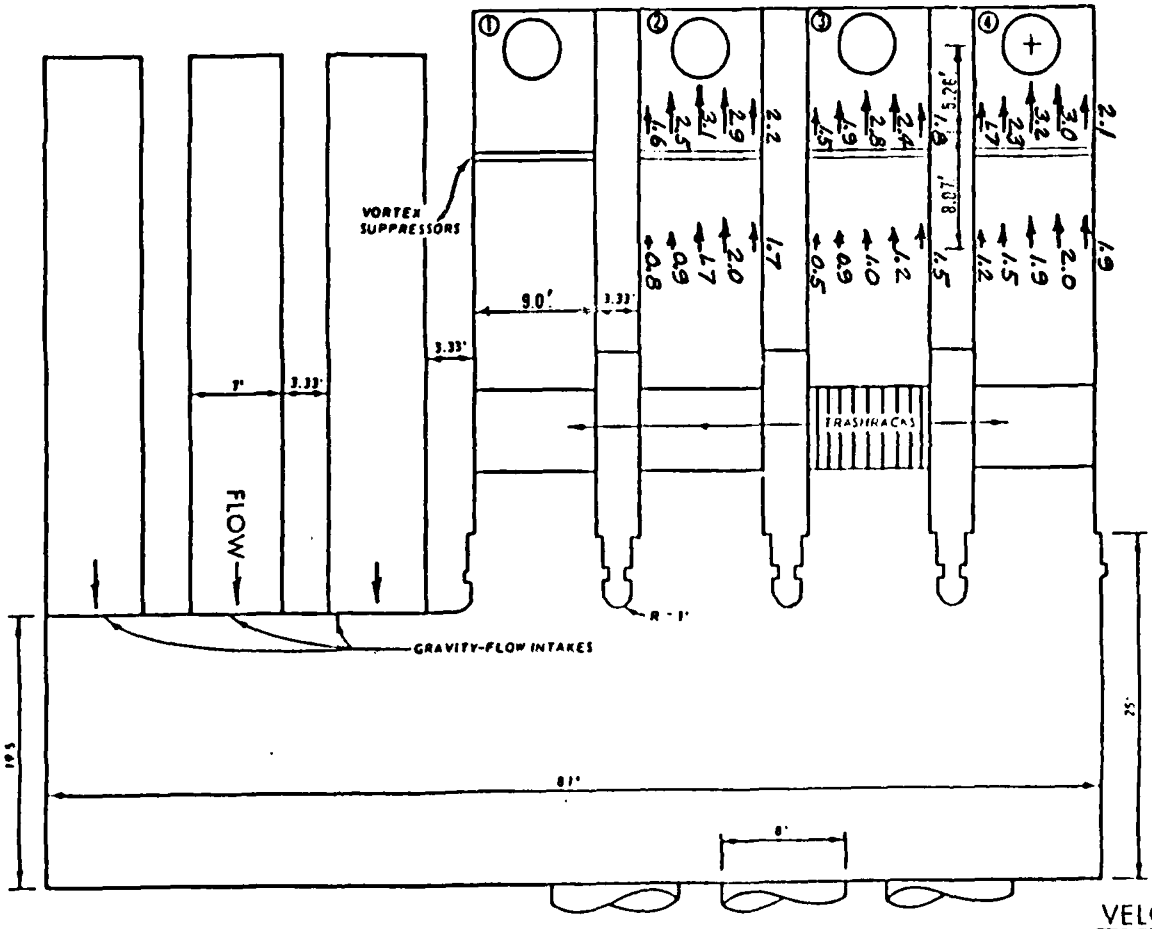
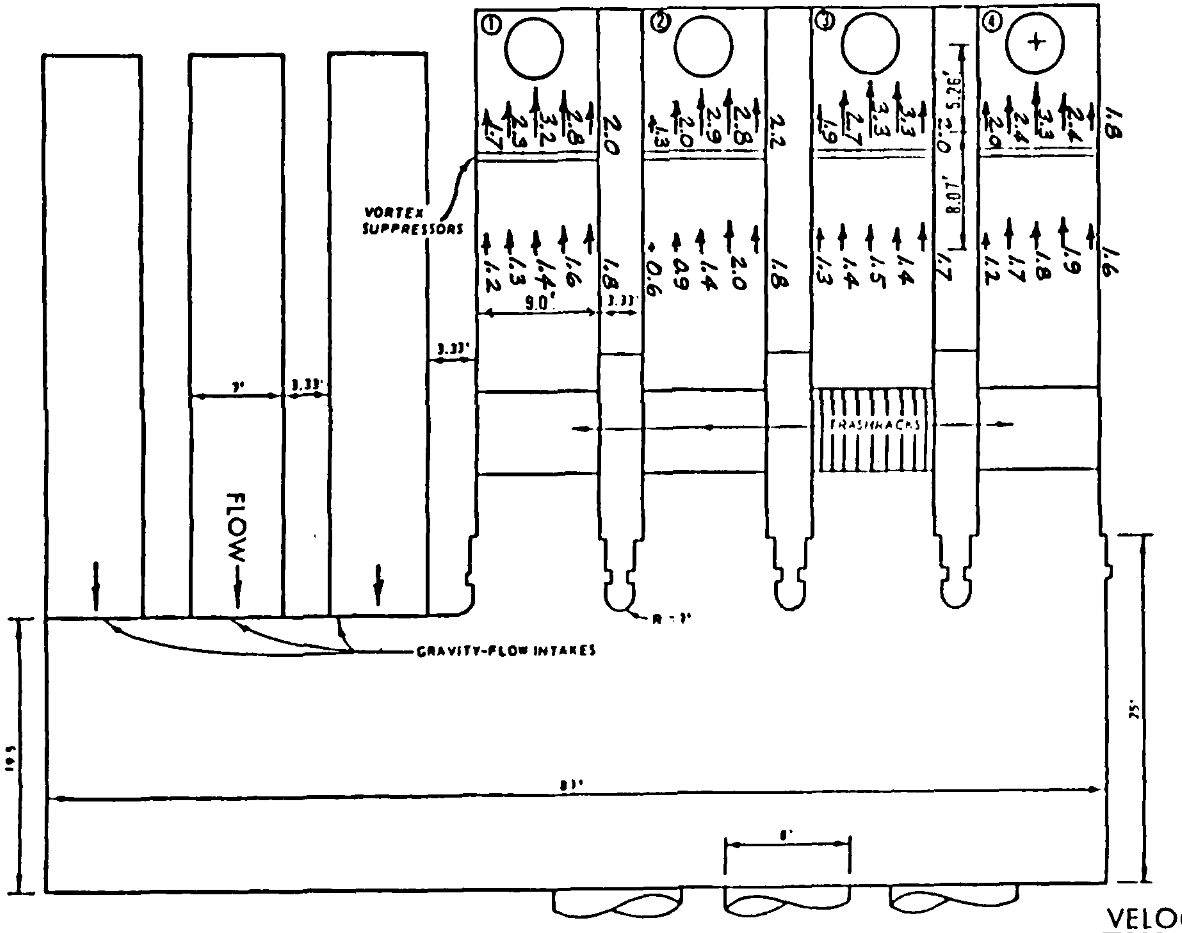

VELOCITY PROFILES
TEST NO. 7
SUMP ELEV. 757
PUMP 3,4
VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM
FLOW
VORTEX SUPPRESSORS
GRAVITY-FLOW INTAKES
TRASHRACKS
9.0'
3.33'
8.07'
5.26'
1.8
2.8
3.2
2.4
1.8
1.5
1.5
1.6
1.5
1.4
1.8
2.3
2.8
2.2
1.7
1.4
1.3
0.9
0.8
0.6

PLATE 12



VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM

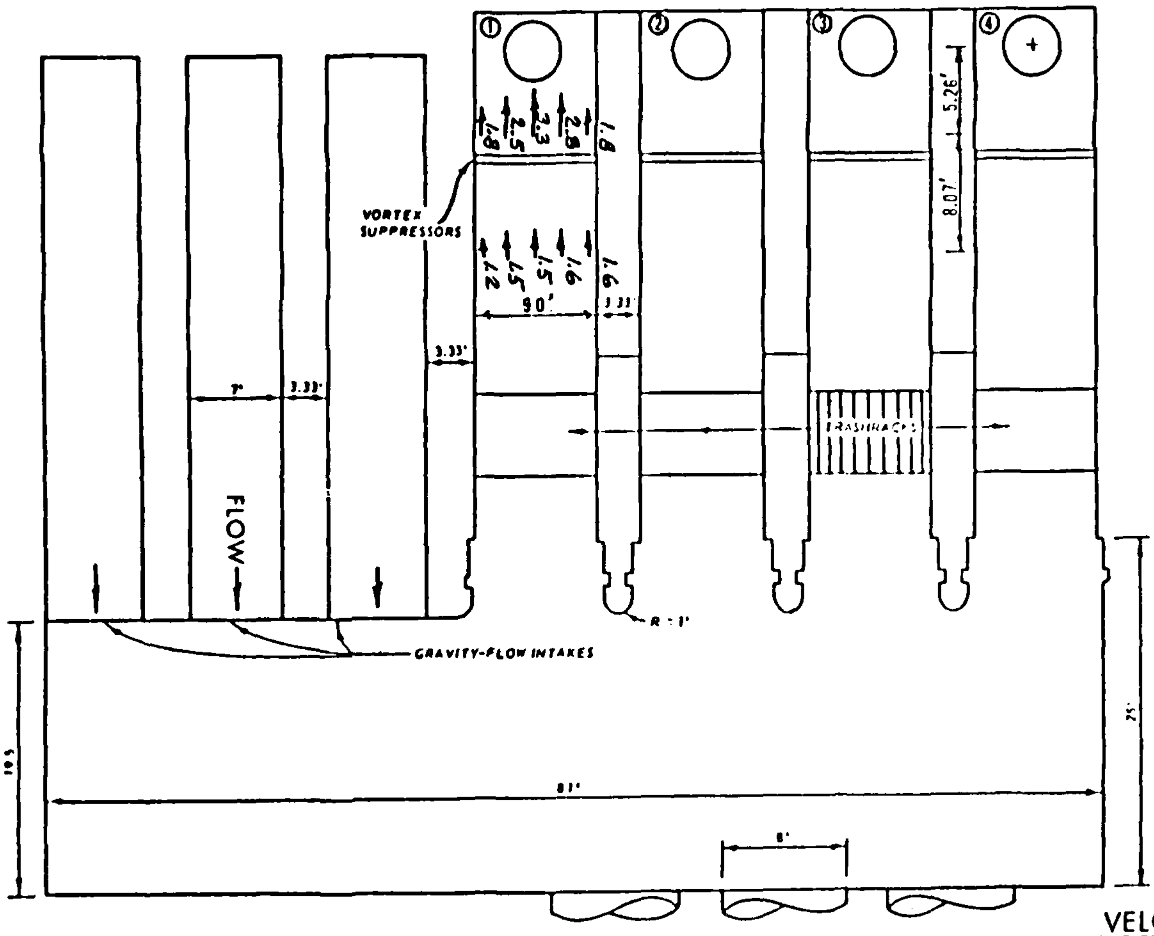
VELOCITY PROFILES
TEST NO. 8
SUMP ELEV. 757
PUMP 2,3,4



VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM

VELOCITY PROFILES
TEST NO. 9
SUMP ELEV. 757
PUMP 1,2,3,4

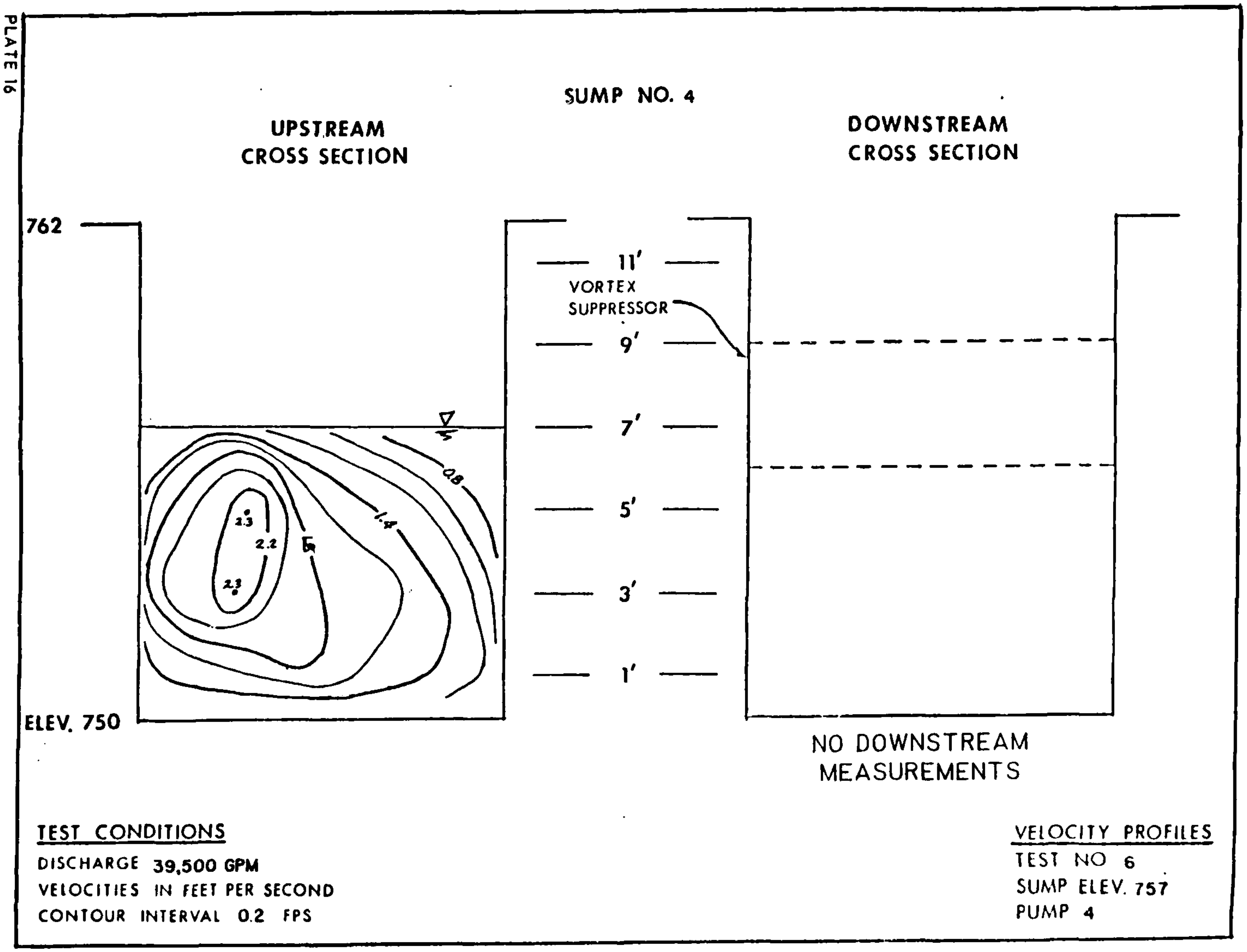
PLATE 14

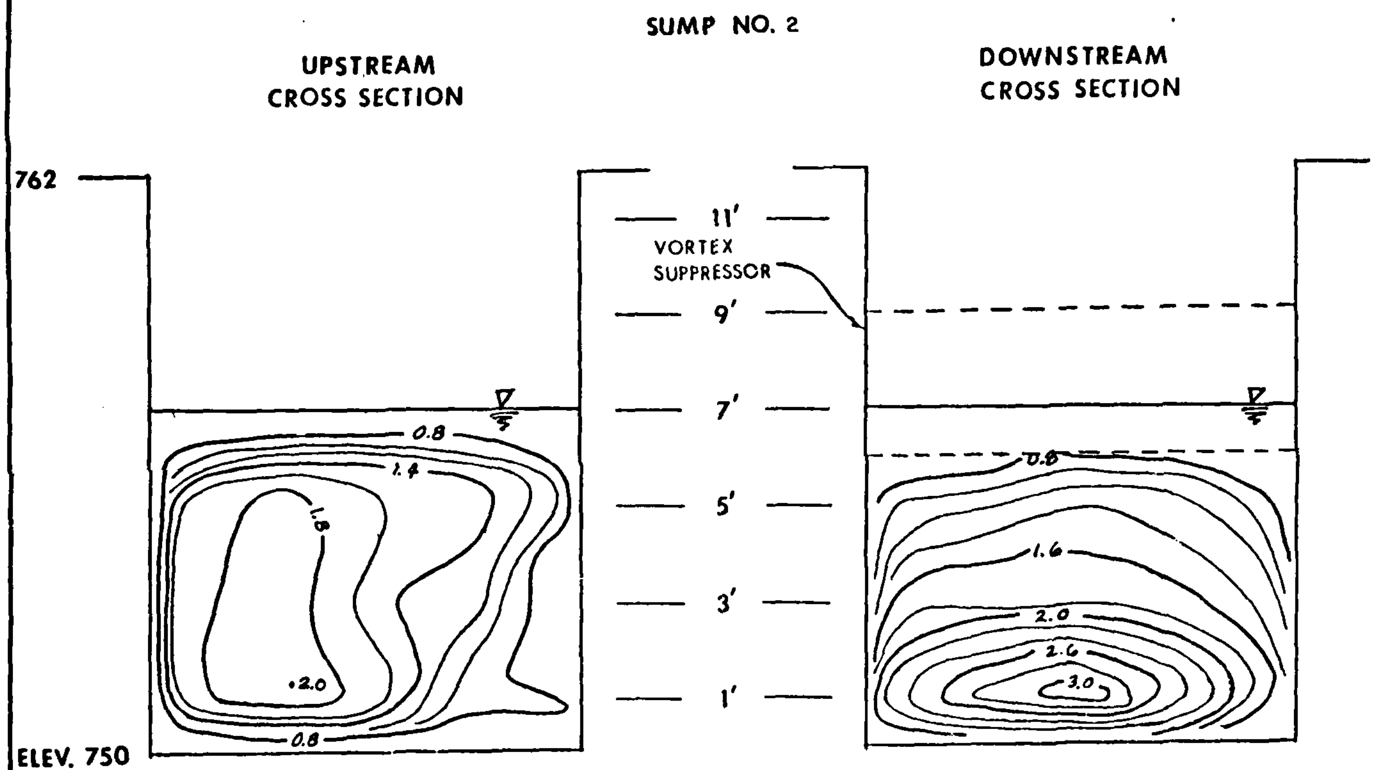


VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM

VELOCITY PROFILES

TEST NO. 10
SUMP ELEV. 757
PUMP 1


SUMP NO. 4
UPSTREAM
CROSS SECTION
DOWNSTREAM
CROSS SECTION
762
ELEV. 750
11'
VORTEX
SUPPRESSOR
9'
7'
5'
3'
1'
0.8
1.4
2.2
2.3
2.3
NO DOWNSTREAM
MEASUREMENTS
TEST CONDITIONS
DISCHARGE 39,500 GPM
VELOCITIES IN FEET PER SECOND
CONTOUR INTERVAL 0.2 FPS
VELOCITY PROFILES
TEST NO 6
SUMP ELEV. 757
PUMP 4

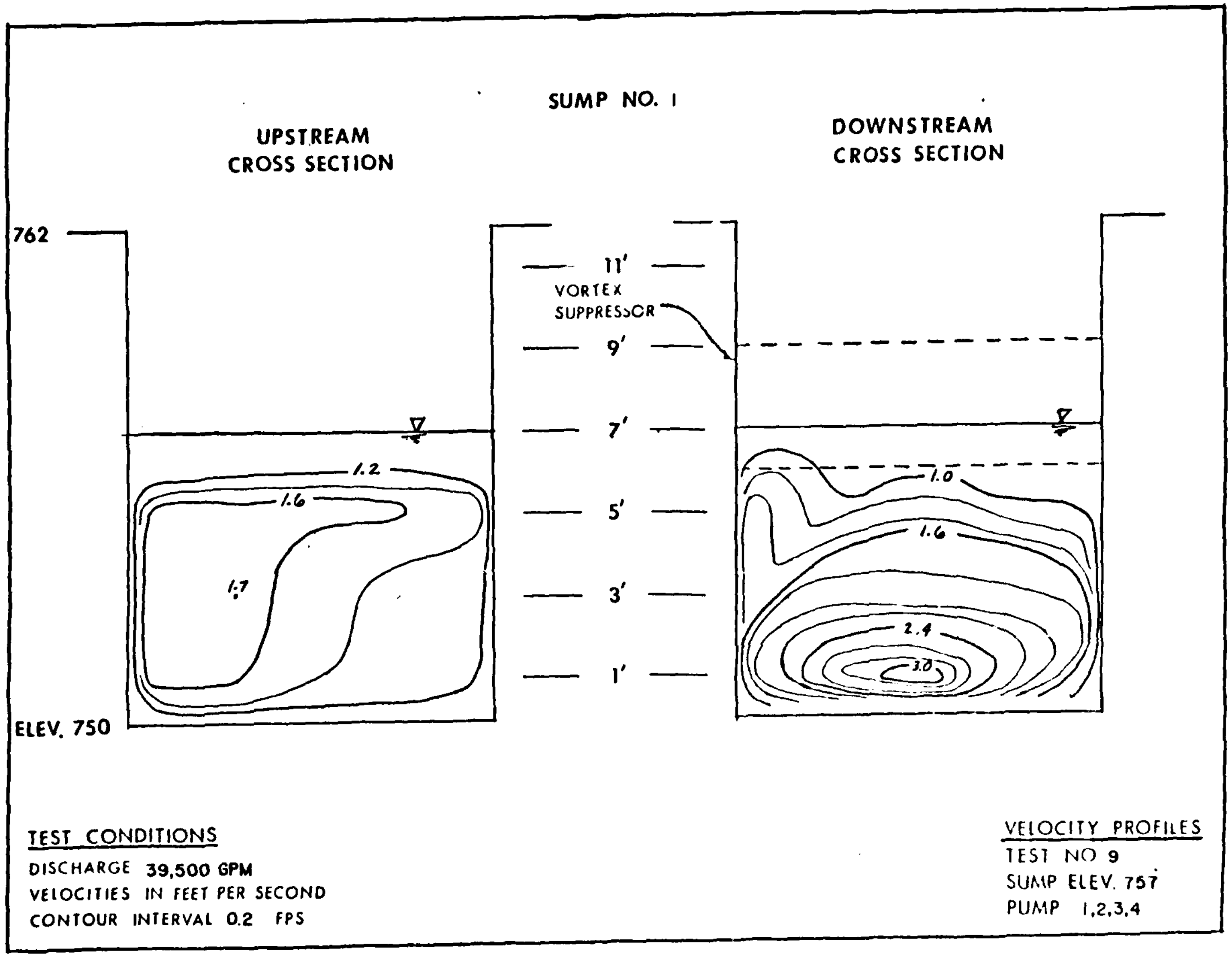


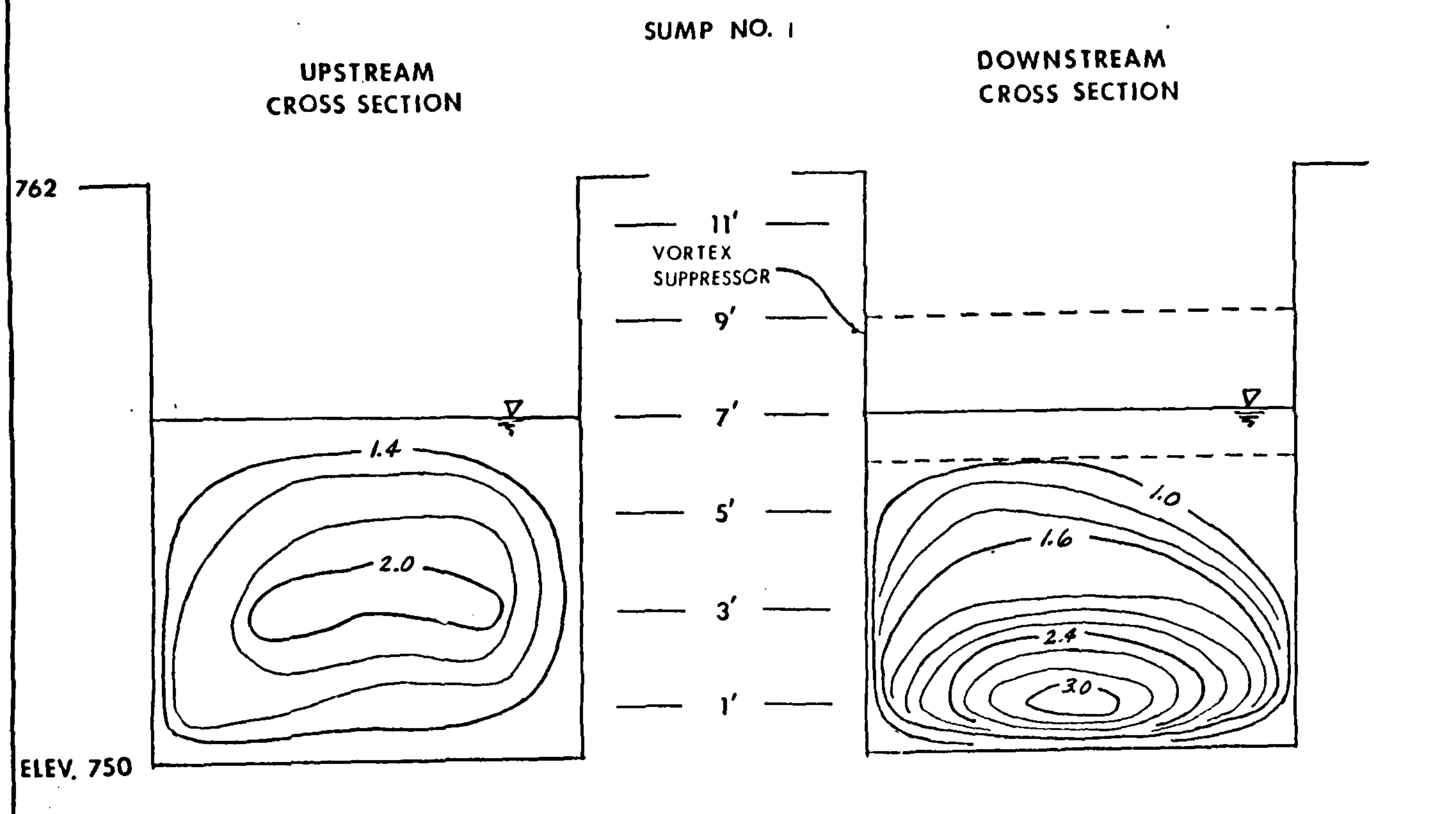
TEST CONDITIONS

DISCHARGE 39,000 GPM
VELOCITIES IN FEET PER SECOND
CONTOUR INTERVAL 0.2 FPS

VELOCITY PROFILES

TEST NO. 8
SUMP ELEV. 757
PUMP 2,3,4


SUMP NO. I
UPSTREAM CROSS SECTION
DOWNSTREAM CROSS SECTION
762
ELEV. 750
11'
VORTEX SUPPRESSOR
9'
7'
5'
3'
1'
1.2
1.6
1.7
1.0
1.6
2.4
3.0
TEST CONDITIONS
DISCHARGE 39,500 GPM
VELOCITIES IN FEET PER SECOND
CONTOUR INTERVAL 0.2 FPS
VELOCITY PROFILES
TEST NO 9
SUMP ELEV. 757
PUMP 1,2,3,4



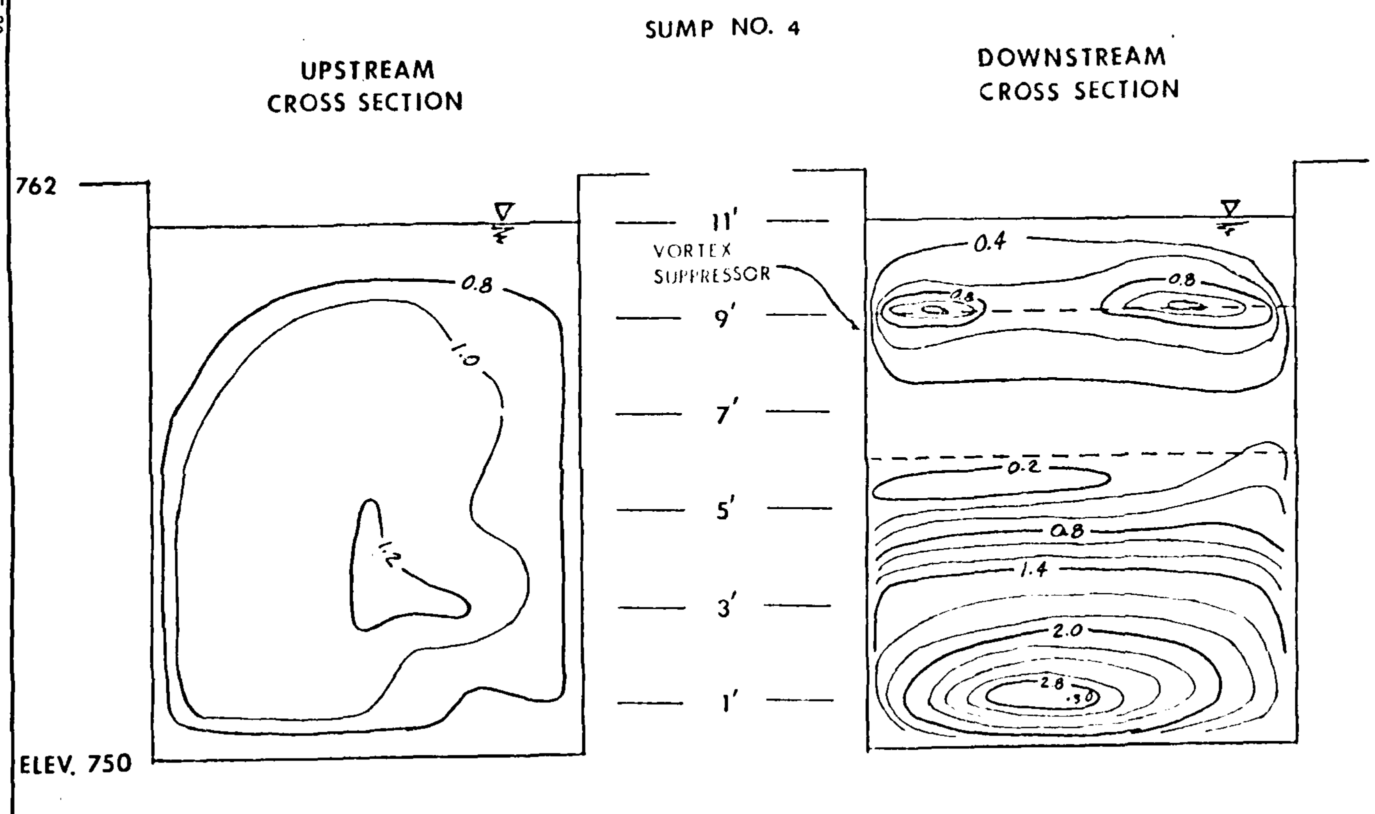
TEST CONDITIONS

DISCHARGE (NO DATA TAKEN)
VELOCITIES IN FEET PER SECOND
CONTOUR INTERVAL 0.2 FPS

VELOCITY PROFILES

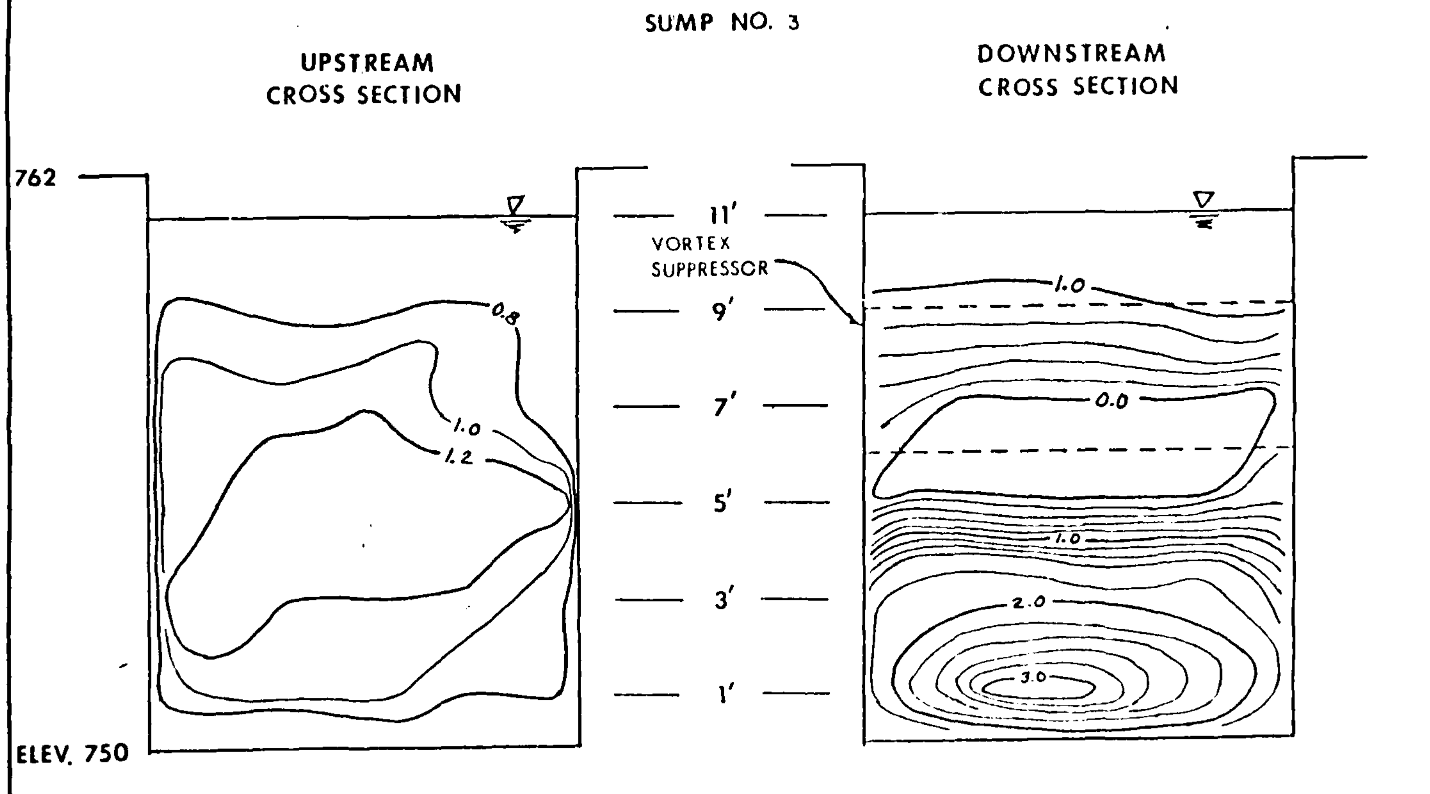
TEST NO. 10
SUMP ELEV. 757
PUMP 1

PLATE 19



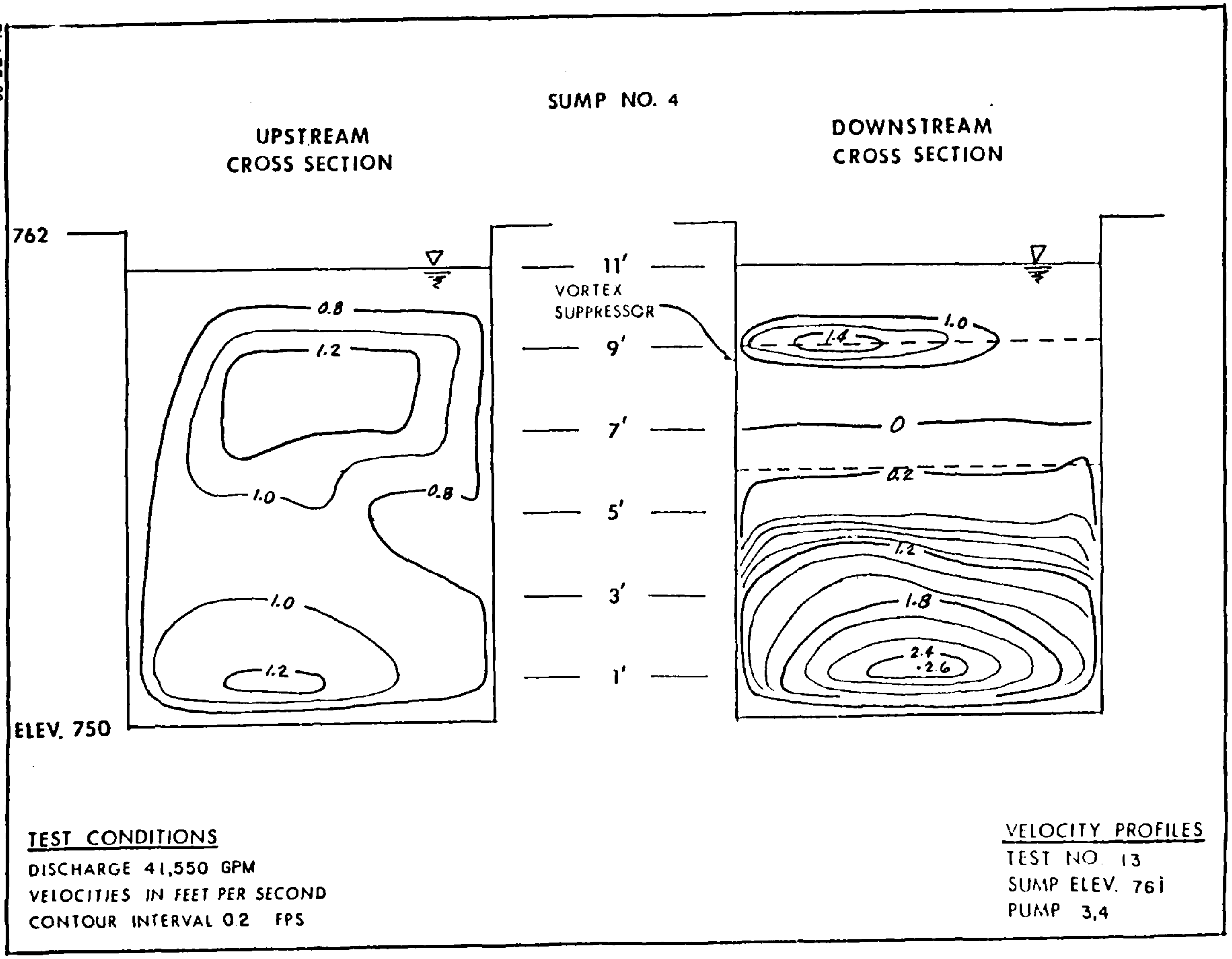
TEST CONDITIONS
DISCHARGE 41,600 GPM
VELOCITIES IN FEET PER SECOND
CONTOUR INTERVAL 0.2 FPS

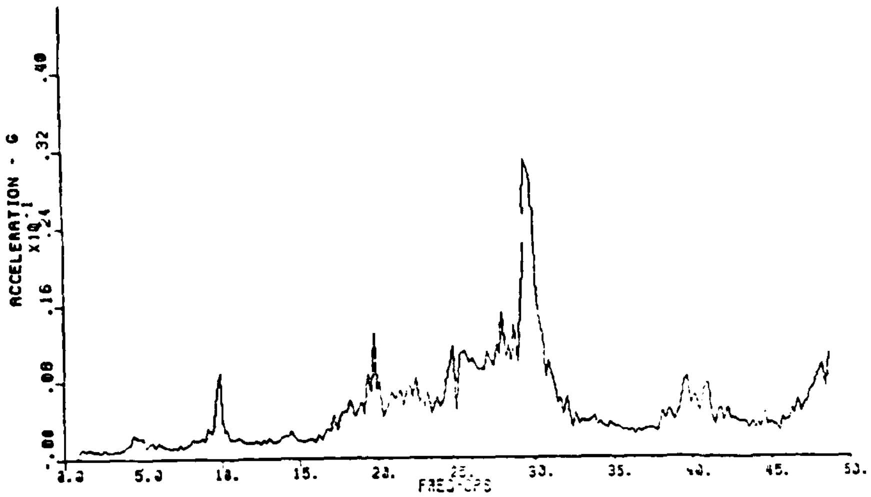
VELOCITY PROFILES
TEST NO 12
SUMP ELEV. 761
PUMP 4



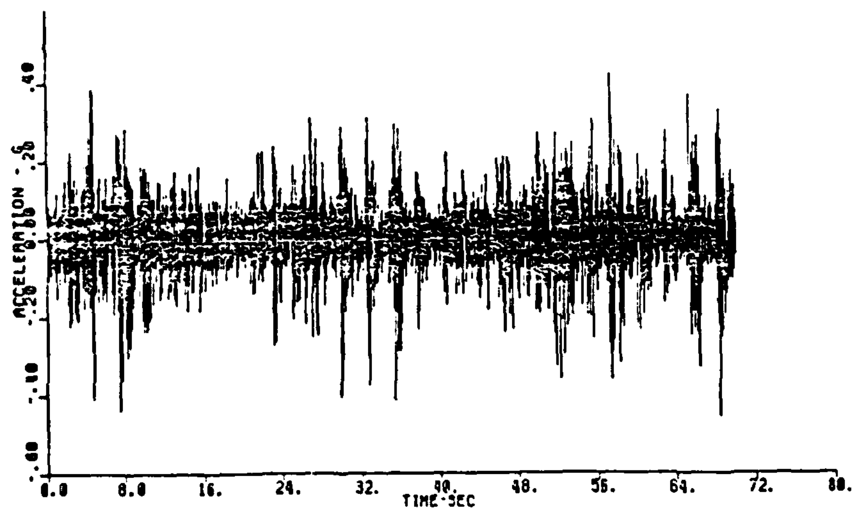
TEST CONDITIONS
DISCHARGE 41,300 GPM
VELOCITIES IN FEET PER SECOND
CONTOUR INTERVAL 0.2 FPS

VELOCITY PROFILES
TEST NO 13
SUMP ELEV 761
PUMP 3,4


SUMP NO. 4
UPSTREAM CROSS SECTION
DOWNSTREAM CROSS SECTION
762
ELEV. 750
11'
9'
7'
5'
3'
1'
VORTEX SUPPRESSOR
0.8
1.2
1.0
0.8
1.0
1.2
1.0
1.4
0
0.2
1.2
1.8
2.4
2.6
TEST CONDITIONS
DISCHARGE 41,550 GPM
VELOCITIES IN FEET PER SECOND
CONTOUR INTERVAL 0.2 FPS
VELOCITY PROFILES
TEST NO. 13
SUMP ELEV. 761
PUMP 3,4



FOURIER TRANSFORM



TIME HISTORY

PUMP COLUMN ACCELERATIONS

DIRECTION TRANSVERSE

TEST 11

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

McGee, Richard G.
Indian Creek Pumping Station Hydraulic Prototype Tests, Mankato, Minnesota / by Richard G. McGee (Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1983.
18 p. in various pagings, 23 p. of plates : ill. ; 27 cm. -- (Miscellaneous paper ; HL-83-4)
Cover title.
"June 1983."
Final report.
"Prepared for U.S. Army Engineer District, St. Paul."

1. Flood control. 2. Hydraulic structures. 3. Pumping stations. I. United States. Army. Corps of Engineers. St. Paul District. II. U.S. Army Engineer Waterways Experiment Station. Hydraulics Laboratory. III. Title IV. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; HL-83-4.
TA7.W34m no.HL-83-4

LMED

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