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HYD 553

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

VERTICAL ADJUSTABLE WEIR

Report No. Hyd-553

Hydraulics Branch
DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

March 1, 1966

HYD 553

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ABSTRACT

Discharge measurement accuracy of a vertically adjustable Cipolletti weir having a 2-ft crest length was investigated in the laboratory. The investigation included determination of head-discharge relationship of the weir and a means of standardizing the method of relating elevation of the movable weir crest to head of water on the crest. Discharges indicated by the weir head were in general in good agreement with discharges measured by volumetrically calibrated Venturi meters for movable crest elevations greater than 0.1 ft above the stationary weir. Reliable discharge measurements could not be made for movable weir crest elevations less than about 0.1 ft above the stationary crest.

DESCRIPTORS-- irrigation canals/ *Cipolletti weirs/ *laboratory tests/ *discharge measurement/ water measurement/ staff gages/ weir crests/ discharge coefficients/ turnouts/ check structures/ aeration/ nappe/ leakage/ research and development/ Venturi meters
IDENTIFIERS-- adjustable weirs

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DEPARTMENT OF THE INTERIOR
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Office of Chief Engineer
Division of Research
Hydraulics Branch
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March 1, 1966

Report No. Hyd-553
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Reviewed by: A. J. Peterka
Submitted by: H. M. Martin

VERTICAL ADJUSTABLE WEIR

SUMMARY AND CONCLUSIONS

A 2-foot adjustable Cipolletti weir was installed in a 4-foot wide flume in the laboratory, Figures 1 and 2. The weir was installed according to the recommendations listed in the first edition of the Water Measurement Manual published by the Bureau of Reclamation.

The purpose of the investigation of the weir was to study the flow characteristics and establish a head-capacity curve for the normal discharge range of a 2-foot Cipolletti weir. A means of standardizing the method of relating the adjustable crest elevation to the head above the fixed crest was developed as part of the study.

Discharges measured with the adjustable Cipolletti weir were in good agreement with discharges measured by Venturi meters volumetrically calibrated in the laboratory. For adjustable crest elevations 0.1 foot and greater above the fixed crest, the discharge indicated by the weir exceeded that measured by the Venturi meters by about 6 percent at a head of 0.2 foot; and 1 percent at a head of 0.6 foot, Figure 6. For weir crest elevations less than about 0.1 foot, the indicated discharges of the weir were less than measured by the meters and the difference in discharges ranged to about 15 percent, Figure 7 and 8. Leakage between the adjustable crest plate and the fixed crest plate was appreciable and helped to reduce the weir accuracy, Figure 5.

The use of two enameled staff gages is proposed for standardizing the method of measuring the weir head. One gage is mounted in the weir pool in a position which is unaffected by the velocity of approach, and the second is attached to the frame which is part of the movable weir blade. Both gages are referenced to the elevation of the fixed crest, Figure 2B, so that a pointer attached to the movable plate would give a direct reading of the crest elevation, and the difference in readings between the upstream and frame-mounted gages, using the water surface as an indicator would give the weir head. This system of gages and pointer proved to be the most satisfactory means of measuring the head above the weir crest.

In irrigation systems where the necessary head is available, the adjustable Cipolletti weir can be used for regulating and measuring discharges with a reasonable degree of accuracy.

When more than one weir is contained in a division box, Figure 4, the necessary proximity of the weirs could have a detrimental influence on the head-capacity relationships of each weir, depending on the weir discharges and the size of the division box. This influence would undoubtedly vary as the separate weirs are adjusted through their ranges of discharge. Whether this influence would be greater than the acceptable range of discharge measurement accuracy could probably be determined by laboratory tests.

INTRODUCTION

Two types of adjustable weirs have been employed for the purpose of measuring and regulating flow in irrigation systems. The first has a horizontal fixed crest and adjustable vertical sides which may be moved to change the size of the rectangular opening. The sides are adjusted by hand, making fine adjustments quite cumbersome.

The Bureau of Reclamation uses a second type called a vertical adjustable weir, Figures 1, 2, 3, and 4. A study of the available literature indicates the weir to be unique in its application to irrigation. The weir assembly includes a movable plate with a Cipolletti weir notch cut out of the center portion (movable weir); another fixed plate (stationary weir) has a large rectangular notch cut out of the central area, Figure 1. The movable weir plate bears against the stationary weir plate and can be adjusted vertically by means of an Acme thread screw and a handwheel placed on a frame at the top of the structure. Although the weir serves as a measuring device, the primary purpose is to control or "check" the flow in a lateral or pump turnout where a variable depth is probable, Figures 3 and 4.

Standardization of the construction details has been accomplished for 2-, 3-, and 4-foot adjustable Cipolletti weirs using an economical design. No reports on malfunction have been found; however, leakage between the fixed and movable plates has been a minor problem in some cases. A complicating factor in the Columbia Basin system is that laterals usually terminate in a rectangular weir box, 5 feet square. The necessary proximity of the two or three adjustable weirs in this box might influence the relative discharge from the weirs and the degree of influence would undoubtedly vary as the separate weirs are adjusted through their range of openings. Whether the discharge error would be greater than the acceptable range of accuracy for the weirs could probably only be determined by laboratory test. However, this aspect of the overall problem was not included in the study.

INVESTIGATION

Laboratory Installation

A 2-foot adjustable weir, obtained on loan from the Black Canyon Irrigation District, Notus, Idaho, was installed in a 4-foot-wide flume in the laboratory, Figures 1 and 2. The flume provided weir pool dimensions equal to those recommended in the first edition of the Water Measurement Manual published by the Bureau of Reclamation. For a field installation, the thickness of the downstream support walls for the weir showed the possibility of affecting the flow by preventing aeration of the weir nappe. The concrete weir wall thickness shown in Section A-A of Figure 1 was simulated in the laboratory by a horizontal piece of wood on the downstream side and at the bottom of the opening of the fixed weir, Figure 2A.

In the original fabrication of the weir, a distortion of the adjustable crest blade prevented contact between the fixed and movable metal plates. In operation, water flowed between the plates. This water was not measured as part of the weir discharge. To correct this, the yoke and stem of the weir were removed to check the bolthole alinement. Inspection showed both a misalinement and a bent yoke. When the yoke was straightened, and the boltholes were alined, the clearance between the metal plate of the weir and the fixed plate was commensurate with the ordinary waviness of No. 12-gage galvanized iron. Leakage between the fixed and movable plates occurred for all positions of the weir crest, however, Figure 5.

Flow through the flume and weir was measured by volumetrically calibrated Venturi meters. The head corresponding to a measured flow through the movable weir was read from an enameled staff gage mounted 5 feet upstream on the side of the flume. A second enameled gage was firmly attached to the frame of the movable weir to provide an accurate indication of the elevation of the movable weir crest above the elevation of the crest of the fixed plate. A pointer attached to the movable plate allowed a direct reading of the crest elevation, Figure 2B. The difference in readings (using the water surface as an indicator) between the upstream gage and the one mounted on the weir frame, both having a zero reference to the elevation of the crest of the fixed blade, provided a measurement of the weir head. The discharge indicated by the weir head was then obtained from standard Cipolletti tables for a 2-foot weir for comparison to the discharge measured by the Venturi meter.

The system for measuring the movable weir crest elevation in the laboratory, as described in the preceding paragraph, differed from that which has been employed in the field. In field installations the adjustable weir crest is set at the same elevation as the fixed weir crest.

A nut is turned down on the Acme thread screw to the top of the nut of the handwheel, Figure 1, and is then pinned or welded in place. After the weir blade is raised, the height of the adjustable crest above the fixed crest can be measured as the distance from the bottom of the nut to the top of the handwheel. The upstream staff gage, referenced at zero to the same elevation as the stationary weir crest, is used to measure the head on the fixed weir. The head on the movable crest is obtained by subtracting the stem measurement from the height of the water surface on the upstream staff gage. Discharges are then determined, using the head, from a Cipolletti weir discharge table. Both the laboratory and field methods of determining the weir head are satisfactory, but the one used in the laboratory can provide the greater accuracy of measurement.

Test Procedure

In a typical calibration test, the movable weir crest was set at the elevation of the top of the stationary crest and a constant flow was allowed to stabilize through the flume. The weir head was then measured on the staff gage located 5 feet upstream from the weir. The weir crest was then raised to elevations of 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, and 0.6 foot above the stationary crest without adjusting the discharge, and the head on the weir was measured for each crest position. This procedure was repeated for eight flows, ranging from 0.06 cfs (cubic feet per second) to a flow of 3.42 cfs, corresponding to a maximum head of approximately one-third of the weir crest length. This is the maximum head recommended for accurate weir measurements.

The leakage flow between the weir bulkhead plate and the movable crest plate was not separately measured because such a measurement would apply directly only to the weir calibrated in the laboratory. It would not apply to other weirs having larger or smaller clearances. Thus, the discharge obtained from the tables for the measured head above the weir crest was not the total flow passing the weir structure but represented the difference between the Venturi measured flow and the leakage flow.

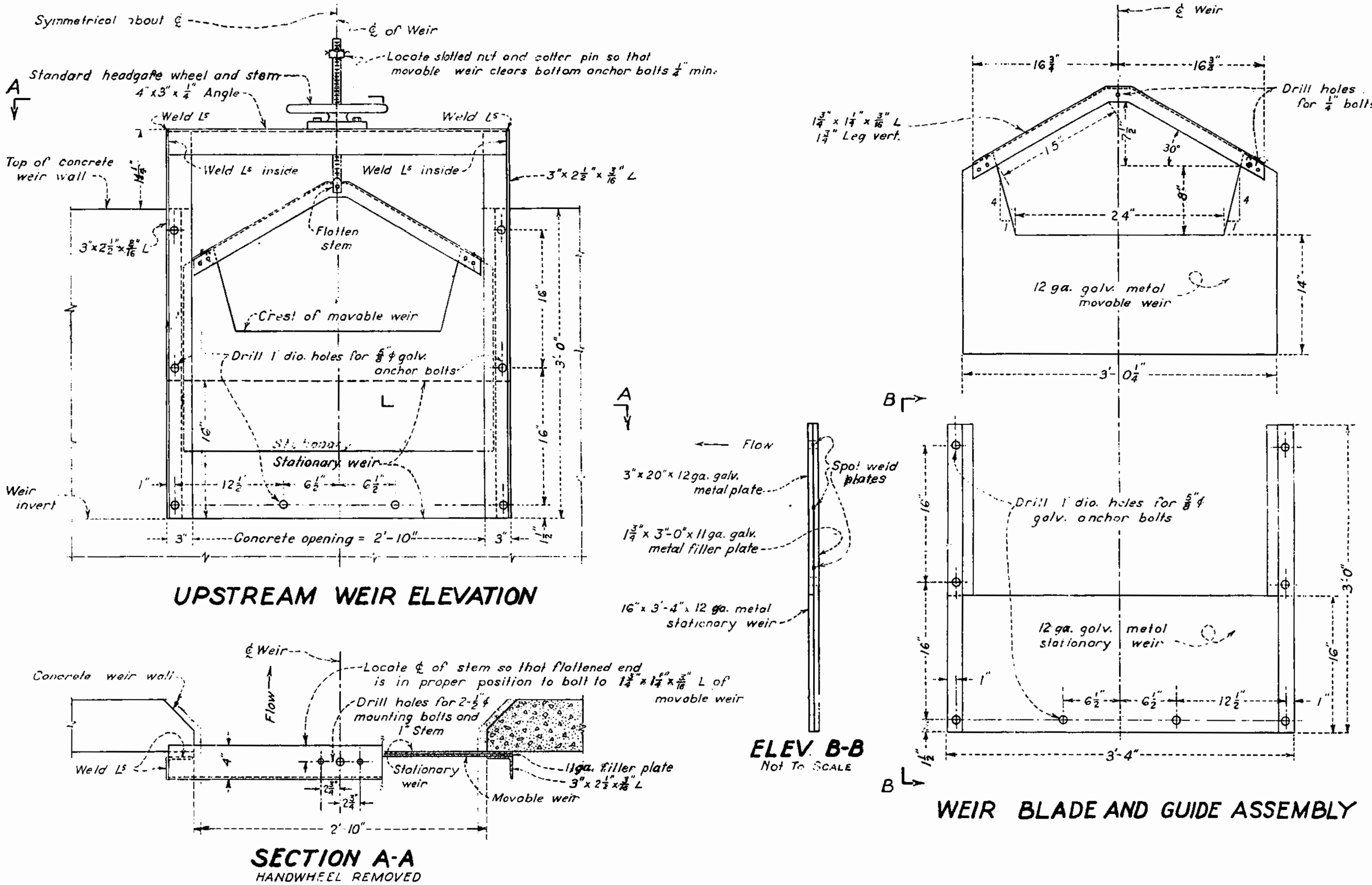
Test Results

The data comparing the discharge measured by the Venturi meter and that indicated by the measured weir head were generalized in three graphs. Figure 6 is for the weir crest 0.10 foot or higher above the stationary crest; Figure 7 is for the weir crest 0.05 foot above the stationary crest; and Figure 8 is for the movable crest elevation equal to the stationary crest elevation.

Proper ventilation of the weir nappe occurred when the weir crest elevation was equal to or greater than 0.1 foot above the elevation of the fixed crest, Figure 5C to F. The discharge indicated by the weir was in good agreement with the Venturi measured discharge in the rated range of head (0.2 to 0.67 foot) for a 2-foot Cipolletti weir, although the total flow included the leakage, Figure 6. Use of the weir at crest elevations higher than 0.1 foot above the fixed crest would produce a means of controlling the flow and discharge measurement. The measurements in these tests showed the weir-indicated-discharge to be about 6 percent greater than the Venturi-measured discharge for a head of 0.20 foot and to be about 1 percent greater for a head of 0.6 foot.

The agreement between the weir-indicated-discharge and Venturi meter was less satisfactory for weir crest elevations of 0.05 and 0.0 foot above the fixed crest elevation, Figures 7 and 8. For a crest elevation of 0.05 foot and heads larger than about 0.4 foot, the agreement between the discharges indicated by the weir and the discharges measured by the Venturi meter was good, Figure 7. Below a head of 0.4 foot, the differences between the measured discharges increased and the weir indicated about 10 percent less flow than the Venturi meter. The suspected cause was the interference between the lower surface of the nappe flowing over the weir crest and the upward flow of the leakage from between the weir plates, Figure 5B.

The discharges indicated by the weir ranged from about 15 percent to 0.5 percent greater than the Venturi for flows of 1 to 3 cfs, respectively, when the elevation of the weir and fixed crests were equal, Figure 8. For discharges below about 1 cfs, the difference between the weir and Venturi discharges was decreased and the weir indicated was about 10 percent less than the meter at a discharge of 0.6 cfs. The weir operating with the crest elevation equal to the fixed crest did not produce accurate discharge measurements, because the thickness of the walls supporting the adjustable weir assembly prevented proper aeration of the weir nappe, Figure 5A.



NOTE

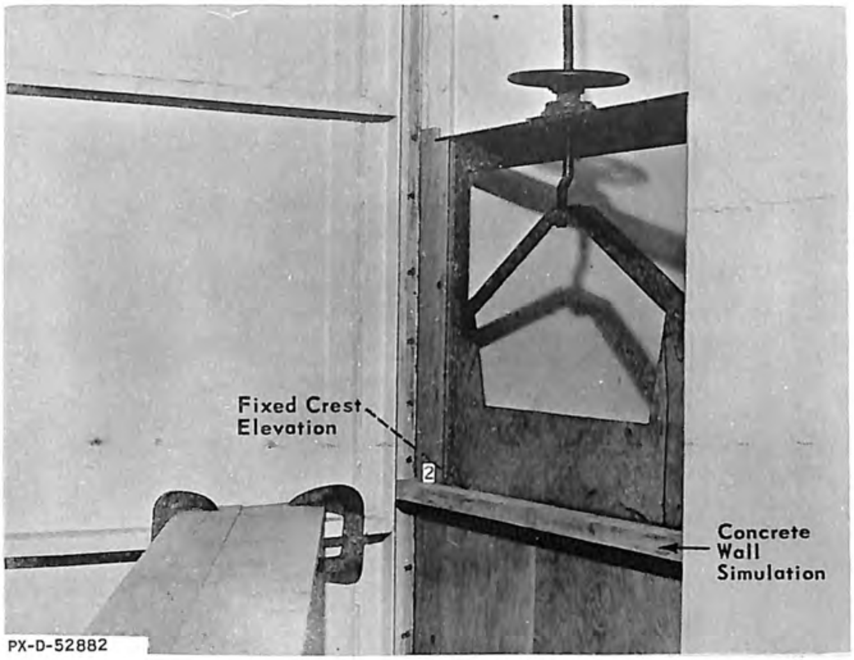
All metal not galvanized shall be protected from rust by paint as directed.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PROJECT

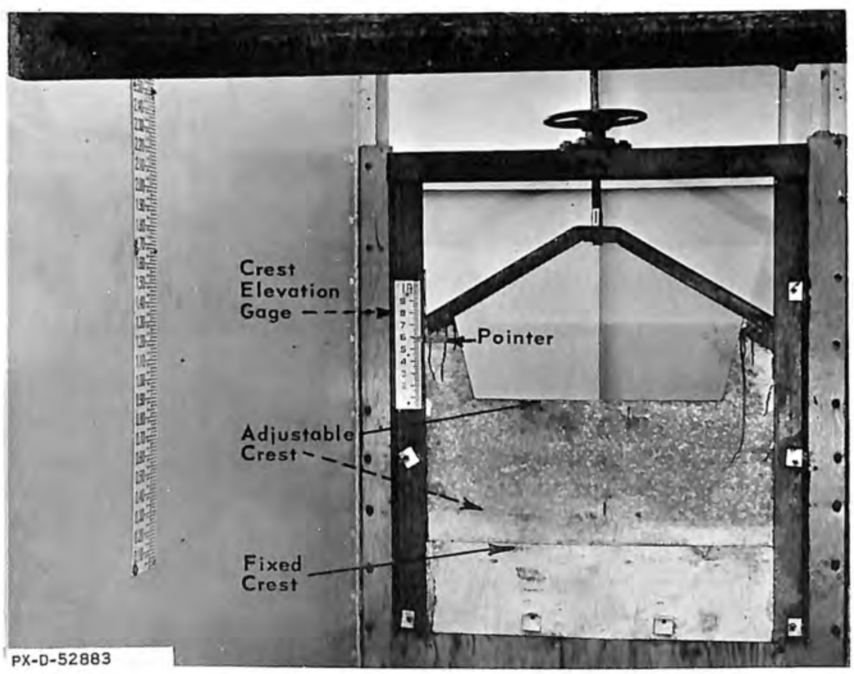
ADJUSTABLE WEIR

DRAWN: F.A.M. SUBMITTED:
TRACED: A.Q.C. RECOMMENDED:
CHECKED: APPROVED:
BOISE, IDAHO. JUNE 12, 1953 X-100-80

FIGURE I
REPORT HYD-553



A. Downstream side of 2-foot adjustable weir



B. Staff gages on upstream side of adjustable weir

ADJUSTABLE CIPOLLETTI WEIR STUDY

Laboratory Installation of Weir

Figure 3
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A. Four-foot adjustable weir used as a combination check and measuring structure--North Side Pumping Division Minidoka Project, Idaho

ADJUSTABLE CIPOLLETTI WEIR STUDY

Field Installation of Weir in Open Channel

A. Pumping plant and adjustable weirs installed in division box

B. Adjustable weirs in division box at discharge end of small pumping plant

ADJUSTABLE CIPOLLETTI WEIR STUDY

Weirs Installed in Pumping Plant Division Box
Columbia Basin Project

A. 0.00 foot

B. 0.05 foot

C. 0.10 foot

Weir Crest Elevation above Fixed Crest

D. 0.20 foot

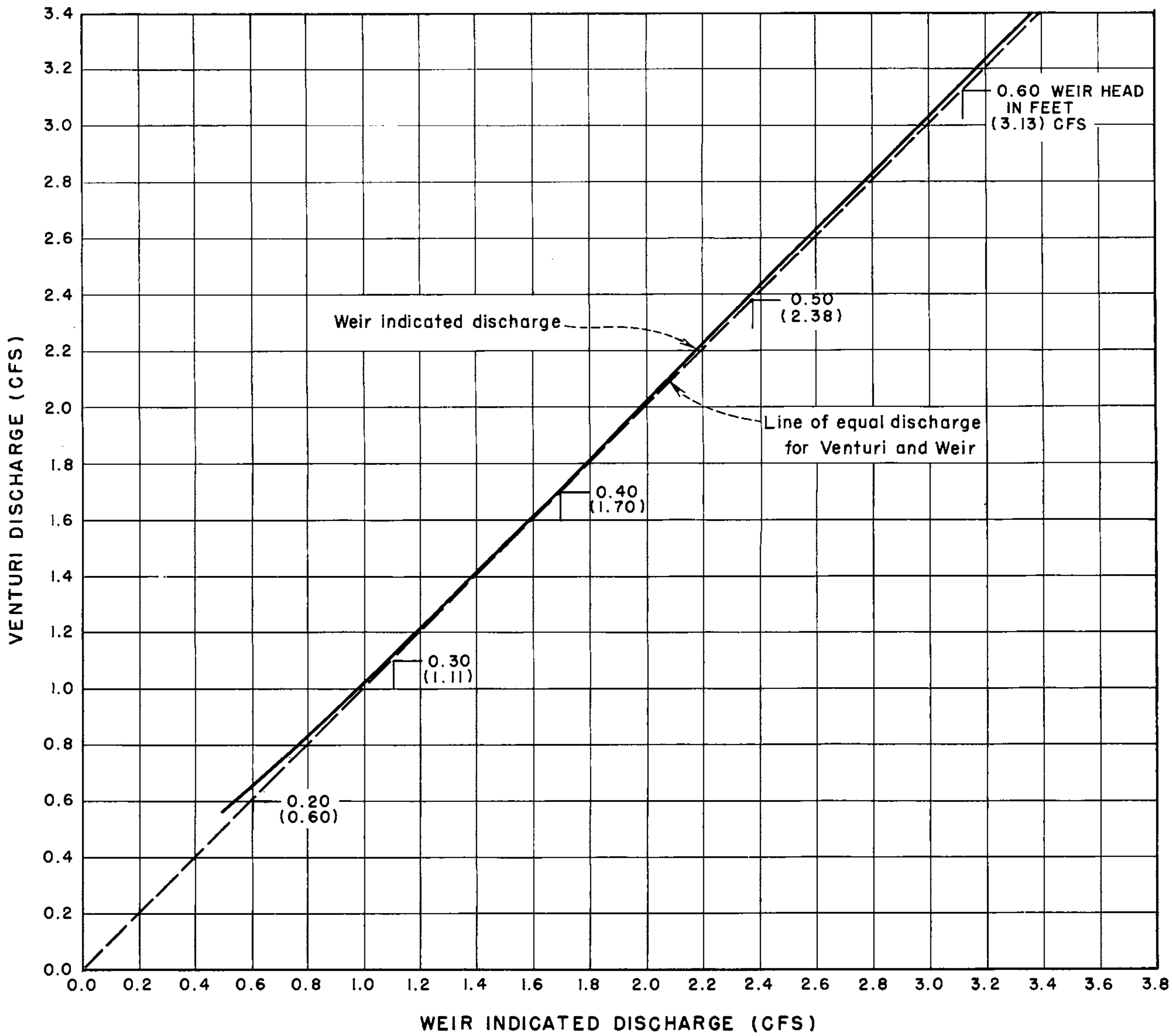
E. 0.40 foot

F. 0.60 foot

Weir Crest Elevation above Fixed Crest

ADJUSTABLE CIPOLLETTI WEIR STUDY

Flow Conditions for Weir Crest Elevations of 0.0 to 0.6 Foot at a Discharge of 1.4 cfs



ADJUSTABLE CIPOLLETTI WEIR STUDY

CAPACITY CURVES FOR
2'-0" WEIR CREST 0.10 FOOT OR HIGHER
ABOVE STATIONARY WEIR CREST

FIGURE 6
REPORT HYD-553

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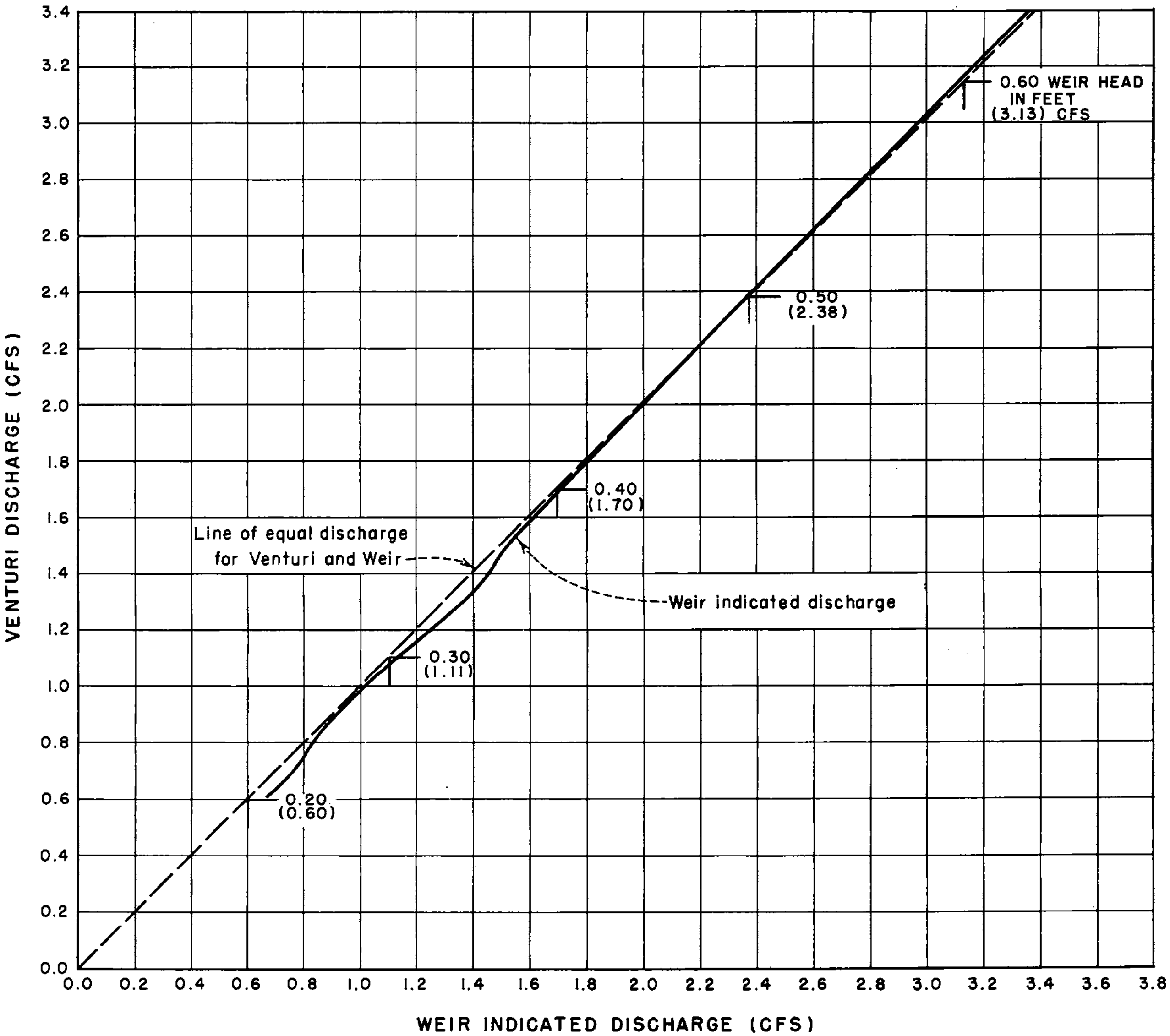
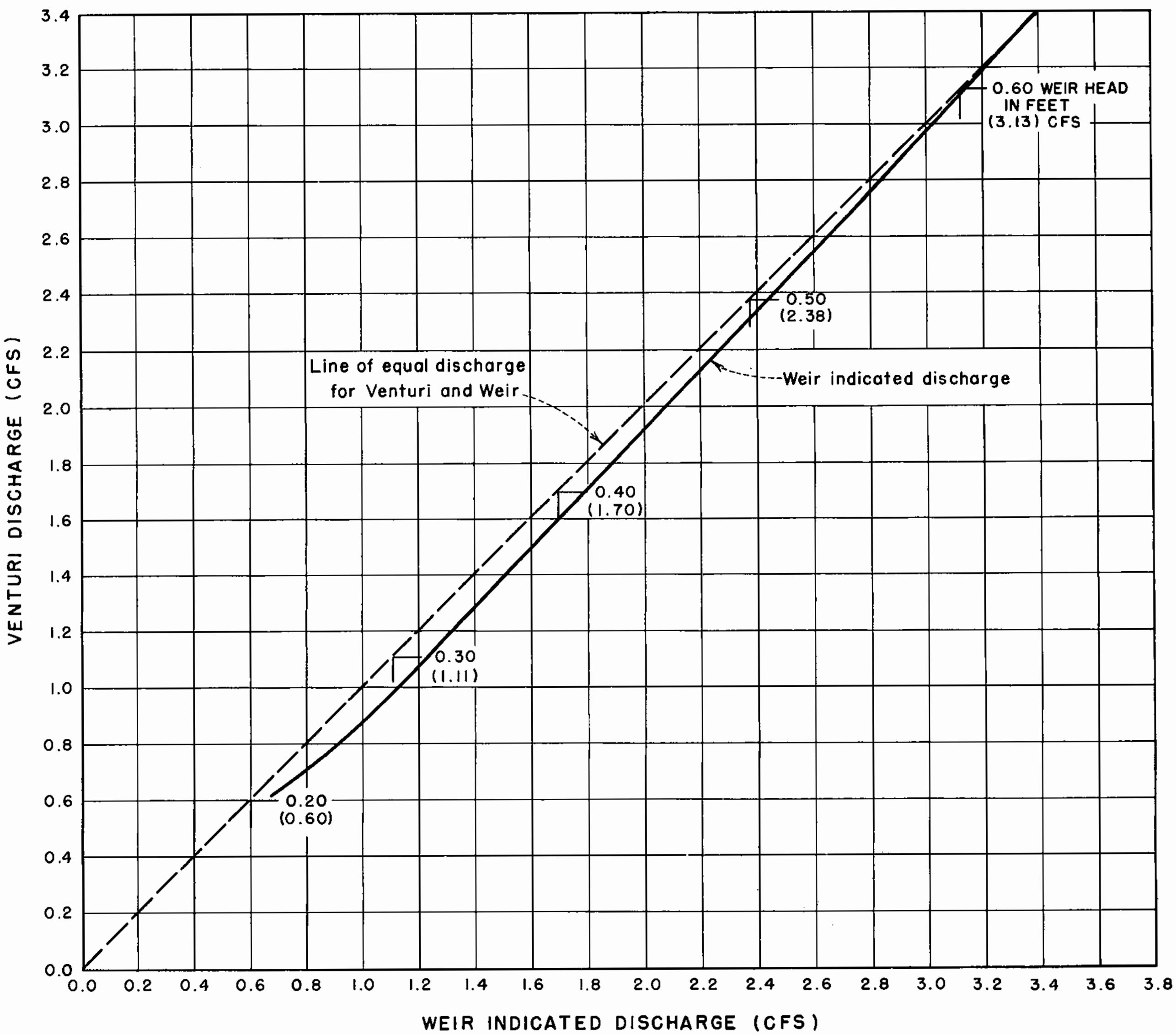


ADJUSTABLE CIPOLLETTI WEIR STUDY

CAPACITY CURVES FOR
2'-0" WEIR CREST 0.05 FOOT ABOVE
STATIONARY WEIR CREST



ADJUSTABLE CIPOLLETTI WEIR STUDY

CAPACITY CURVES FOR
2'-0" WEIR CREST 0.00 FOOT ABOVE
STATIONARY WEIR CREST

FIGURE 8
REPORT HYD-553

GPO 856-721

CONVERSION FACTORS--BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, January 1964) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given on pages 10-11 of the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg; that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Table 1

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03 (exactly)*	Square centimeters
	0.092903 (exactly)	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	0.0040469*	Square kilometers
Square miles	2.58999	Square kilometers
	VOLUME	
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
	CAPACITY	
Fluid ounces (U.S.)	29.5737	Cubic centimeters
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	9,463.58	Cubic centimeters
	0.946358	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	1,233,500*	Liters

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
	1.12985×10^{6}	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582×10^{7}	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
	0.3048 (exactly)*	Meters per second
Feet per year	0.965873×10^{-6}*	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	0.3048*	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	0.028317*	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
FORCE*		
Pounds	0.453592*	Kilograms
	4.4482*	Newtons
	4.4482×10^{-5}*	Dynes
WORK AND ENERGY*		
British thermal units (Btu)	0.252*	Kilogram calories
	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	1.35582*	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	0.09290*	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	304.8*	Liters per square meter per day
Pound-seconds per square foot (viscosity)	4.8824*	Kilogram second per square meter
Square feet per second (viscosity)	0.02903* (exactly)	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	35.3147*	Millicuries per cubic meter
Milliamps per square foot	10.7639*	Milliamps per square meter
Gallons per square yard	4.527219*	Liters per square meter
Pounds per inch	0.17858*	Kilograms per centimeter

GPO 845-237

ABSTRACT

Discharge measurement accuracy of a vertically adjustable Cipolletti weir having a 2-ft crest length was investigated in the laboratory. The investigation included determination of head-discharge relationship of the weir and a means of standardizing the method of relating elevation of the movable weir crest to head of water on the crest. Discharges indicated by the weir head were in general in good agreement with discharges measured by volumetrically calibrated Venturi meters for movable crest elevations greater than 0.1 ft above the stationary weir. Reliable discharge measurements could not be made for movable weir crest elevations less than about 0.1 ft above the stationary crest.

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