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HYDRAULIC MODEL STUDIES OF JACKSON LAKE DAM BAFFLE BLOCKS

P. H. Burgi
Division of Research
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March 1970

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16. Abstract

Model studies of the Jackson Lake Dam sluice outlets were conducted to determine the effectiveness of the existing baffle blocks. Tests were run without baffle blocks, with baffle blocks, and with an end sill. Evaluation of the various configurations was based on scour patterns resulting from each test. Tests without baffle blocks resulted in a prohibitive scour pattern. The end sill yielded a slight improvement in the scour pattern over that of the existing baffle blocks. Sluice operating arrangements were suggested.

17. Key Words

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by

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March 1970

HYDRAULICS BRANCH
DIVISION OF RESEARCH

UNITED STATES DEPARTMENT OF THE INTERIOR * BUREAU OF RECLAMATION
Office of Chief Engineer . Denver, Colorado

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PURPOSE

The purpose of the study was to investigate the effectiveness of the existing baffle blocks which have been damaged by abrasion over the years. Tests were conducted with the existing baffle blocks, with an end sill, and without baffle blocks.

RESULTS

1. Erosion was quite severe without the baffle blocks, especially at the end of the apron where undercutting occurred.

2. Placement of baffle blocks on the apron similar to the prototype configuration, considerably reduced the severity of erosion of the downstream channel.

3. A continuous baffle or end sill proved somewhat more effective than the baffle blocks in controlling erosion at the end of the apron. However, the slight improvement in the scour pattern with the end sill does not justify a change in the existing apron baffle block configuration.

4. To retard the formation of the large eddy along the sides of the downstream channel (Figure 2), releases greater than 3,500 cfs (99.109 cu m per second) should be made in groups of two or three adjacent operating sluices separated by spaces of at least three adjacent inoperative sluices (Table 1). Releases through the end sluices 2, 3, 18, and 19 should also be considered in combination with the central sluices for discharges greater than 3,000 cfs (84.950 cu m per second).

APPLICATIONS

This investigation was limited in scope to a specific structure. Further application would be limited to similar structures with similar operating conditions.

INTRODUCTION

Jackson Lake Dam, located on the Snake River in northwestern Wyoming near Moran within the boundaries of the Grand Teton National Park, was initially completed in 1911 and in 1916 was raised 17 feet (5.182 m) to a structural height of 55 feet (16.764 m). The dam is a concrete gravity section with earth embankment wings at each end of the concrete section. The concrete section is 222 feet (67.666 m) long with twenty 8.0-foot (2.438-m) by 6.5-foot (1.981-m) sluiceways through the section near the base and a radial gate controlled overfall spillway consisting of seventeen 8.0-foot (2.438-m) bays and two 10.0-foot (3.048-m) bays.

Deterioration of the existing concrete baffle blocks on the apron downstream from the sluiceways and extensive scour of the channel bed immediately downstream of the apron indicated the need for a study to evaluate the effectiveness of the existing blocks as compared to a continuous baffle or end sill.

THE MODEL

The model, built to a 1:15 scale ratio, represented the 100-foot (30.480-m) right half of the dam, including six operative sluices and gates (sluices 5–10), four nonoperative sluices (sluices 1–4), 75 feet (22.860 m) of the downstream channel, and 180 feet (54.864 m) of the reservoir (Figure 1). The model was of wood construction except for the six gates which were made of sheet metal. The downstream channel was formed of a 6-inch- (15.240-cm-) deep layer of pea gravel.

Since the model encompassed only the right half of the dam, a wall of symmetry was placed at the tenth pier and extended through the tailbox. The spillway was not included in the model.

Water was supplied to the model through the permanent laboratory system and was measured by one of a bank of venturi meters installed in the laboratory. The tailwater elevation was controlled by an adjustable gate.

The six sluices included in the model proved to be a limitation on the number of sluice operating combinations that could be investigated. The depth and length of the pea-gravel channel were also insufficient, resulting in an inaccurate scour pattern at the downstream end of the tailbox. In spite of these limitations, the tests yielded sufficiently accurate scour patterns at the end of the apron to make qualitative judgments of the various baffle configurations and to determine optimum sluice operating arrangements. In this report all dimensions refer to the prototype, unless otherwise noted.

THE INVESTIGATION

Four discharges representing 1,000, 2,000, 3,500 and 4,500 cfs (28.317, 56.634, 99.109, 127.426 cu m per second) were tested.

Prototype operating conditions are such that when the total discharge from the reservoir is greater than 2,500 cfs (70.792 cu m per second) and less than 5,000 cfs (141.584 cu m per second), 500 cfs (14.158 cu m per second) flows over the spillway and the remainder is discharged through the sluices at the rate of 500 cfs (14.158 cu m per second) per sluice.

A discharge of 1,000 cfs (28.317 cu m per second) flows over the spillway for total discharges of 5,000 cfs (141.584 cu m per second) or greater. Tailwater in the model was set to represent the total discharge in the prototype. Model tests were made using 1, 2, 3, or 4 sluices, which represented 2, 4, 6, or 8 sluices discharging 500 cfs (14.158 cu m per second) each in the prototype.

Three apron configurations were tested; namely, without baffle blocks, with baffle blocks, and with a continuous baffle, or sill, across the end of the apron. The effectiveness of each configuration was evaluated on the basis of the scour pattern after completion of each test. Each test was approximately an hour and thirty minutes long allowing time for the scour pattern to stabilize.

The reservoir head for all tests was held at an elevation representing 41 feet (12.497 m) above the sluiceway floor. The tailwater was adjusted for each test based on tailwater discharge data 1,000 feet (304.800 m) downstream from the dam.

Apron without Baffle Blocks

The flow dove off the apron at all discharges without baffle blocks on the apron causing severe erosion of the downstream channel (Figure 2). Depending on the sluice operating arrangement adopted, the flow leaving the apron either enhanced or retarded the formation of the large eddy along the right side of the downstream channel (Figure 2A). For instance, when sluices 5, 7, 8 and 10 were operated simultaneously the eddy was much more intense than when sluices 5, 6, 8 and 10 were operated simultaneously.

Apron with Baffle Blocks

Baffle blocks representing the existing prototype blocks were installed on the apron. The baffle blocks deflected the flow upward and spread it in such a manner that it fell in a parabolic pattern (Figure 3A). This baffle block configuration resulted in considerable less scour than the earlier tests without blocks (Figures 2B and 4B). The scour at the end of the apron occurred where the path of the large eddy impinged on the pea gravel. As in the earlier tests, the scour pattern at the end of the apron depended on the sluice operating arrangement adopted (Figure 4). The pea gravel which appears on the apron and in some of the sluiceways was a result of initializing the tests and was not caused by the flow pattern after the tests were in operation.

Apron with End Sill

The end sill had a 1:2.4 slope on the upstream face, identical to the outside profile of the existing baffle blocks (Figure 1). It also deflected the flow upward, but more of the flow was concentrated at the vertex of the parabola (Figure 3B). When using 1, 2, or 3 sluices in the model representing discharges of 1,000, 2,000, or 3,500 cfs (28.317, 56.634, 99.109 cu m per second), respectively, the scour pattern at the end of the apron was somewhat improved over the scour pattern that had formed with the baffle blocks (Figures 5, 6, and 7). When four sluices representing 4,500 cfs (127.426 cu m per second) were operated, the scour pattern was virtually the same as had formed with the baffle blocks (Figures 4A, 9C, 4B, and 9B).

Sluice Operating Arrangements

The high velocity jets discharging from the sluices depressed the tailwater at the apron thus creating a tailwater differential. The tailwater differential caused an upstream flow or eddy. When no intermediate upstream flow channels could be established between the jets, the upstream flow was concentrated in a large eddy along the right side of the downstream channel (Figure 2A). In the prototype there would also be another eddy along the left side of the downstream channel.

To investigate intermediate flow channels three sluice operating arrangements were tested for the 4,500 cfs (127.426 cu m per second) discharge with the end sill (Figure 8). The best flow conditions resulted when two inoperative sluices were placed between groups of adjacent operating sluices.

Figure 8A illustrates the tendency for an upstream flow between the operating jets. Since the tailwater differential was somewhat reduced by this return flow, the eddy was not as strong. Figure 9 shows the respective scour patterns of the tests in Figure 8. Figure 9A shows a slight improvement in the scour pattern immediately downstream of the apron as a result of the two-sluice spacing between operating sluices.

Limitations of the model did not permit the testing of a sluice operating arrangement consisting of three inoperative sluices between groups of adjacent operating sluices. The improvement of the flow pattern achieved by using a two-sluice spacing between operating sluices indicated that a three-sluice spacing would provide even greater improvement. As a result of these tests, a spacing of at least three sluices between groups of adjacent operating sluices is recommended, see Table 1.

Further improvement in the general flow pattern downstream of the sluices could be realized by operating the sluices near both abutments, sluices 2, 3, 18 and 19, when the total discharge exceeds 3,000 cfs (84.950 cu m per second). Such operation would retard the formation of the large eddy along the sides of the downstream channel.

Table 1

RECOMMENDED SLUICE OPERATING ARRANGEMENTS

Q_T* cfs (cu m per second)	Sluice No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2,000 (56.634)				X		0		0	X				X 0		0		X			
3,500 (99.109)		X		0		X	0		0	X	X	0		0	X		0		X	
4,500 (127.426)		X	X	0		0	X	X 0		0	0	X	X 0		0		X 0	X		
5,500 (155.742)		X	X 0	X	0		0		X 0	X 0	X	0		0		X 0	X	X 0		

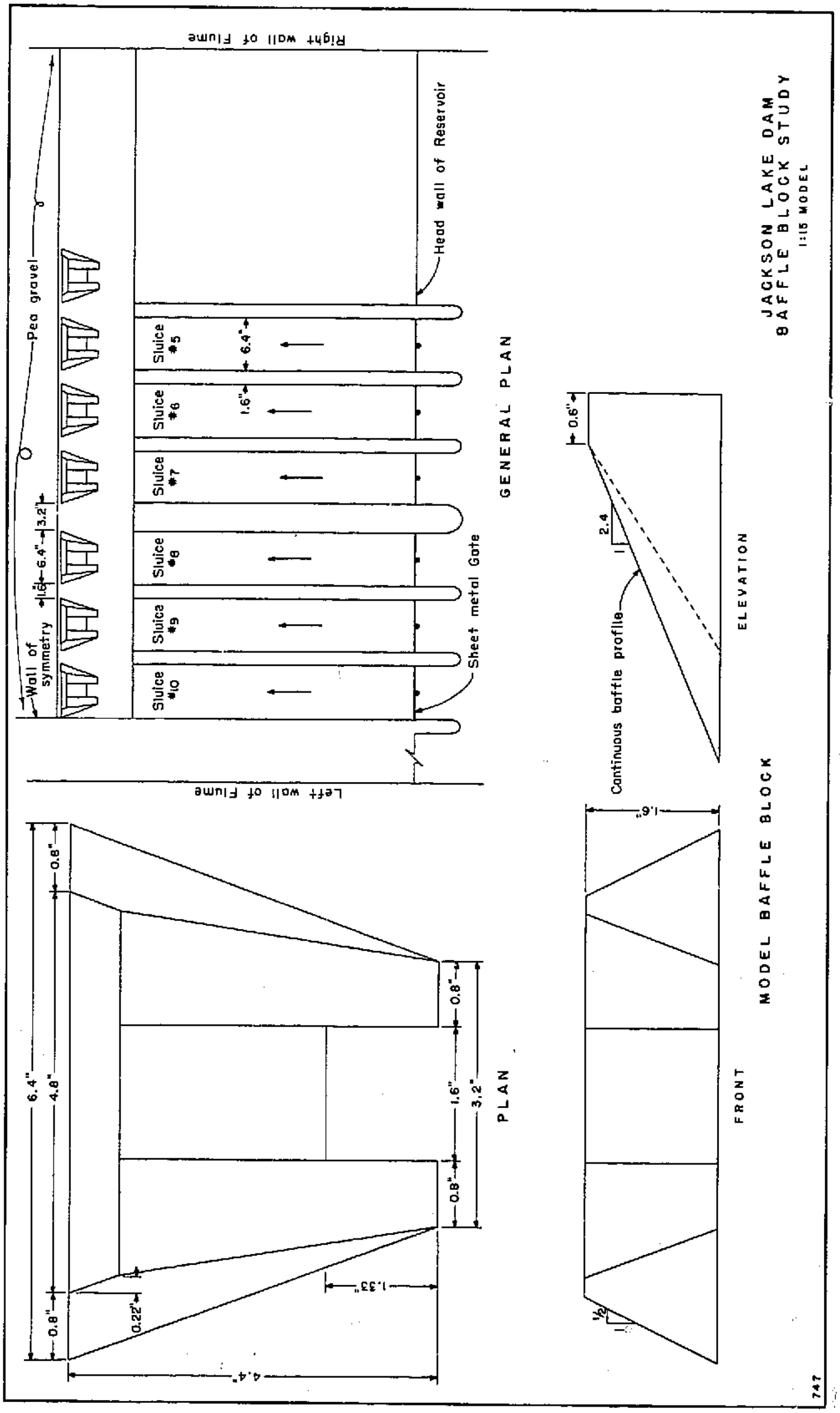
*$Q_T = Q_{Sluice} + Q_{Spillway}$

X = Recommended sluice operating arrangements

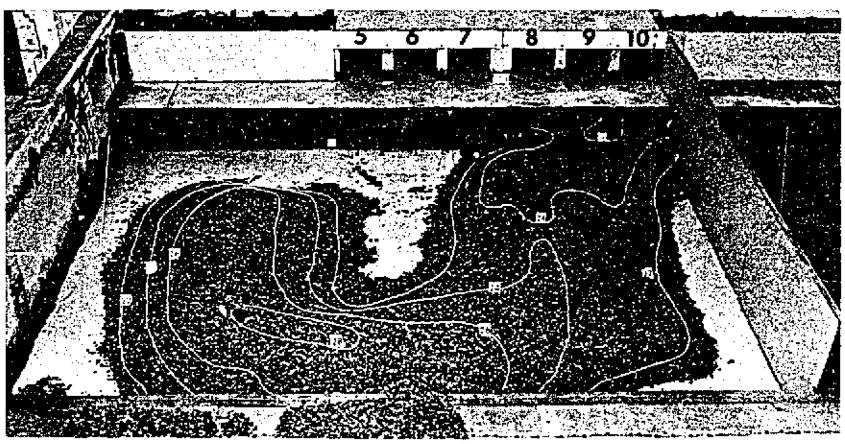
0 = Existing sluice operating arragements

For discharges of 6,000 cfs (169.901 cu m per second) and larger, the spillway discharge along with the higher tailwater should eliminate the tailwater differential present at lower discharges.

FIGURE 1


JACKSON LAKE DAM
BAFFLE BLOCK STUDY
1:15 MODEL
GENERAL PLAN
Right wall of Flume
Left wall of Flume
Head wall of Reservoir
Pea gravel
Wall of symmetry
Sluice #5
Sluice #6
Sluice #7
Sluice #8
Sluice #9
Sluice #10
Sheet metal Gate
6.4"
1.6"
3.2"
ELEVATION
0.6"
2.4
1
Continuous baffle profile
MODEL BAFFLE BLOCK
PLAN
FRONT
6.4"
4.8"
0.8"
1.6"
3.2"
0.22"
1.33"
4.4"
1.6"
1/2
1
747

A. Large eddy, reservoir elevation 6769.0, tailwater elevation 6732.0. Photo P17-D-66276

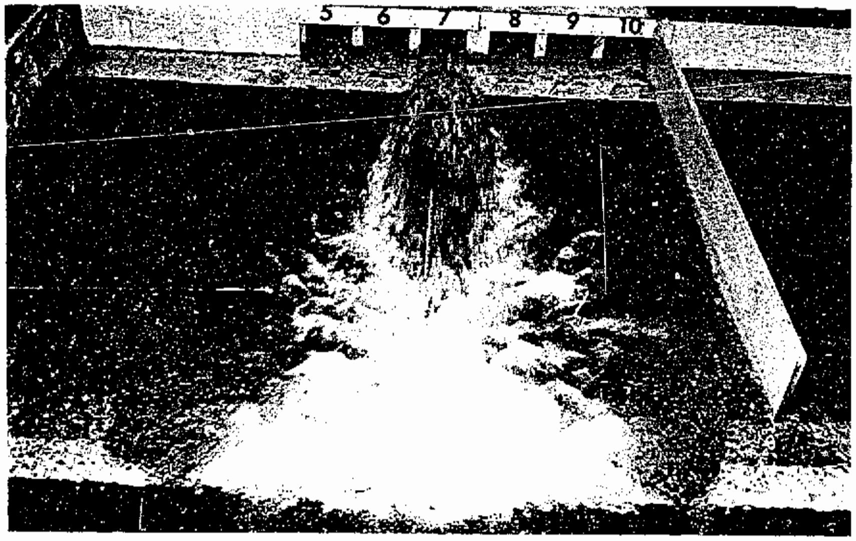


B. Resulting scour pattern. Photo P17-D-66277

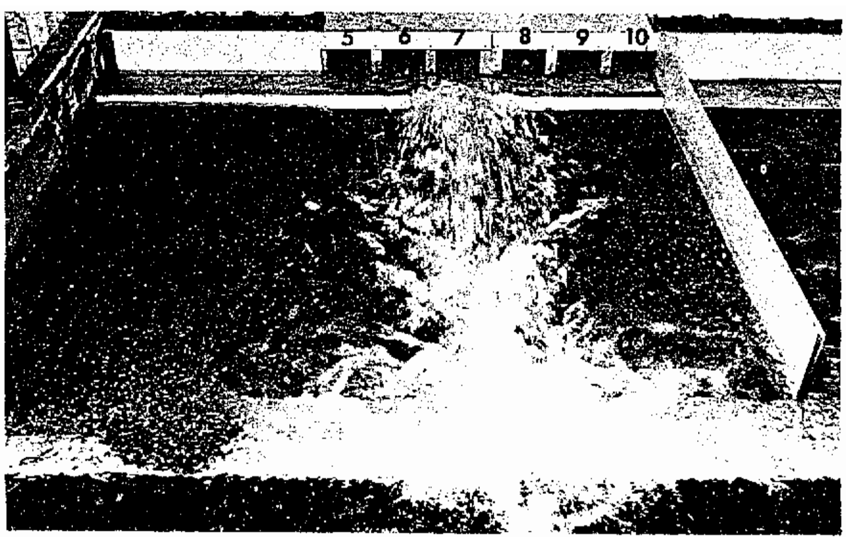
JACKSON LAKE DAM
BAFFLE BLOCK STUDY

Flow and Erosion Patterns
without Baffle Blocks
Sluices 5, 7, 8, and 10, Q = 4,500 cfs
(127.426 m^3/sec)
1:15 Model

FIGURE 3



A. Baffle blocks on apron. Photo P17-D-66278

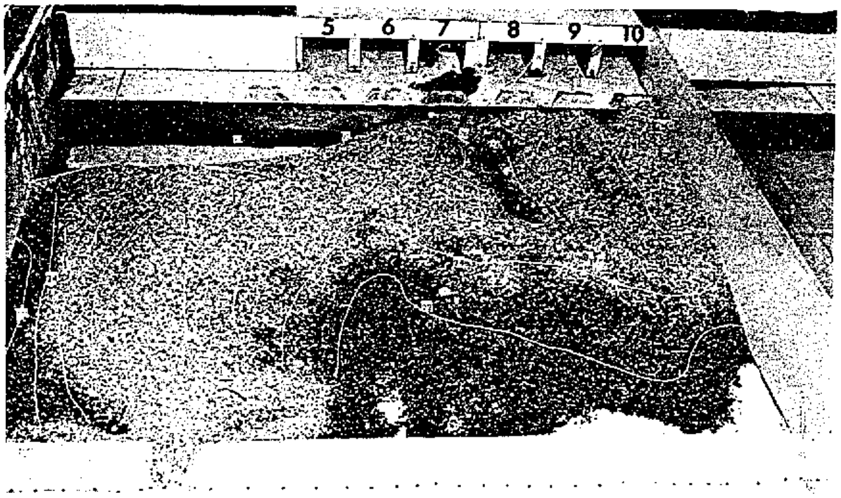


B. End sill on apron. Photo P17-D-66279

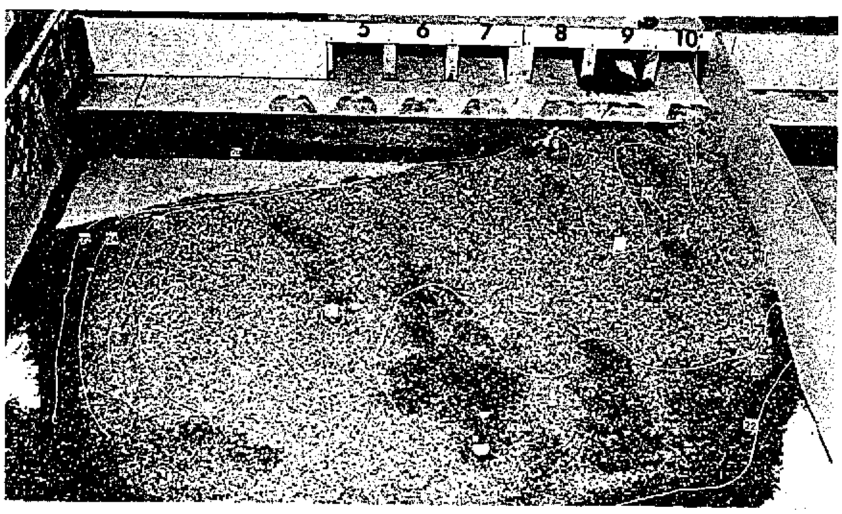
JACKSON LAKE DAM
BAFFLE BLOCK STUDY

Comparison of Baffle Blocks and
End Sill with Flow through
Sluice 7, Q = 1,000 cfs (28.317 m^3/sec)
1:15 Model

FIGURE 4



A. Sluices 5, 6, 8, and 10. Photo P17-D-66280

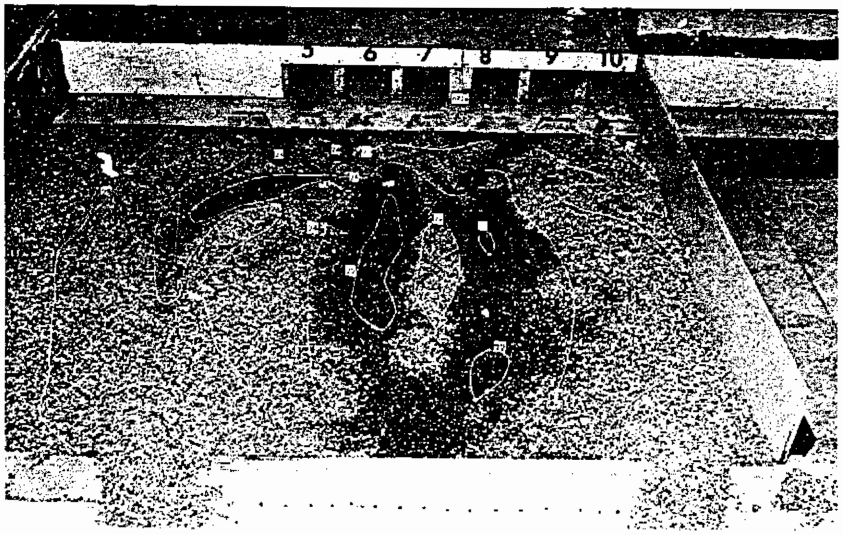


B. Sluices 5, 7, 8, and 10. Photo P17-D-66281

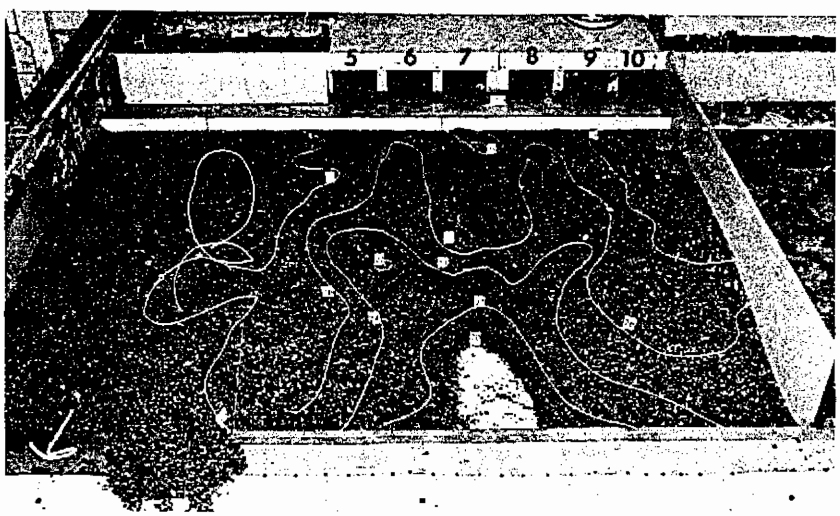
JACKSON LAKE DAM
BAFFLE BLOCK STUDY

Resulting Scour Patterns from
4,500 cfs (127.426 m^3/sec) Discharge
with Existing Baffle Blocks
1:15 Model

FIGURE 5



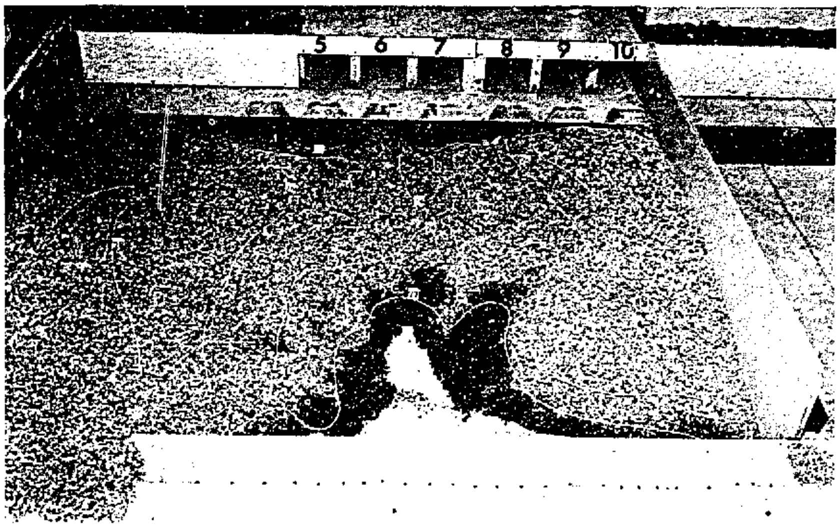
A. Baffle blocks on apron. Photo P17-D-66282



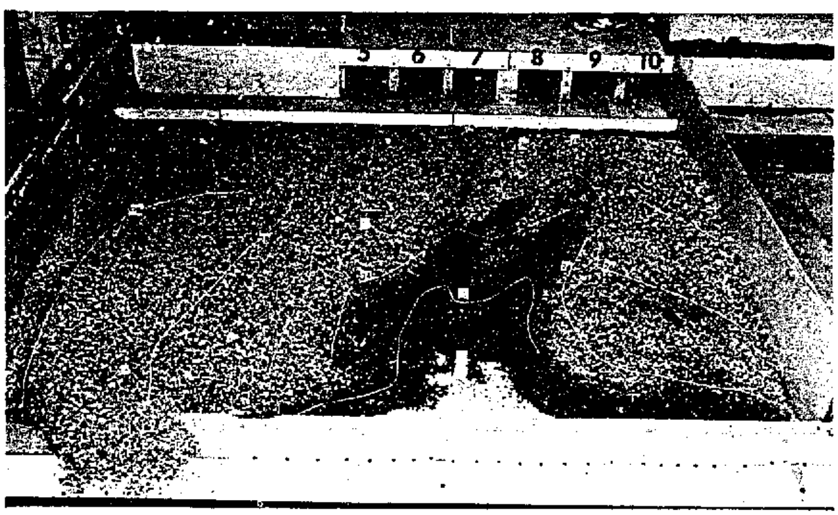
B. End sill on apron. Photo P17-D-66283

JACKSON LAKE DAM
BAFFLE BLOCK STUDY

Resulting Scour Patterns
from 1,000 cfs (28.317 m^3/sec) Discharge
1:15 Model



A. Baffle blocks on apron. Photo P17-D-66284

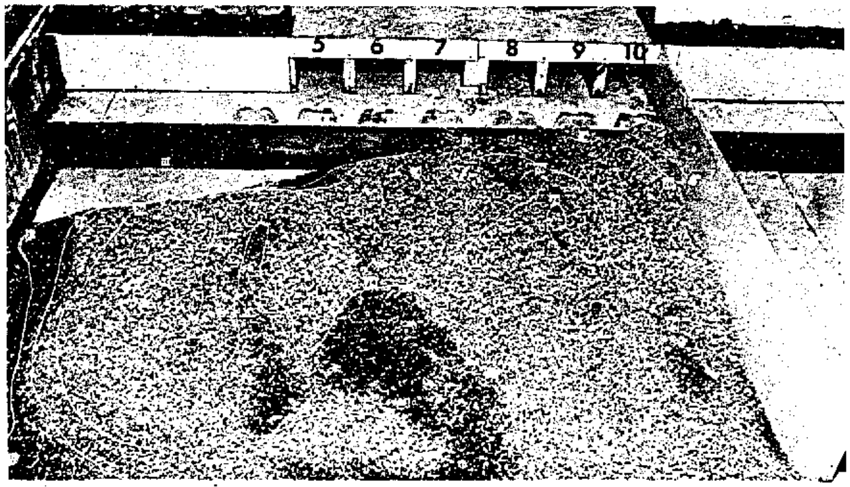


B. End sill on apron. Photo P17-D-66285

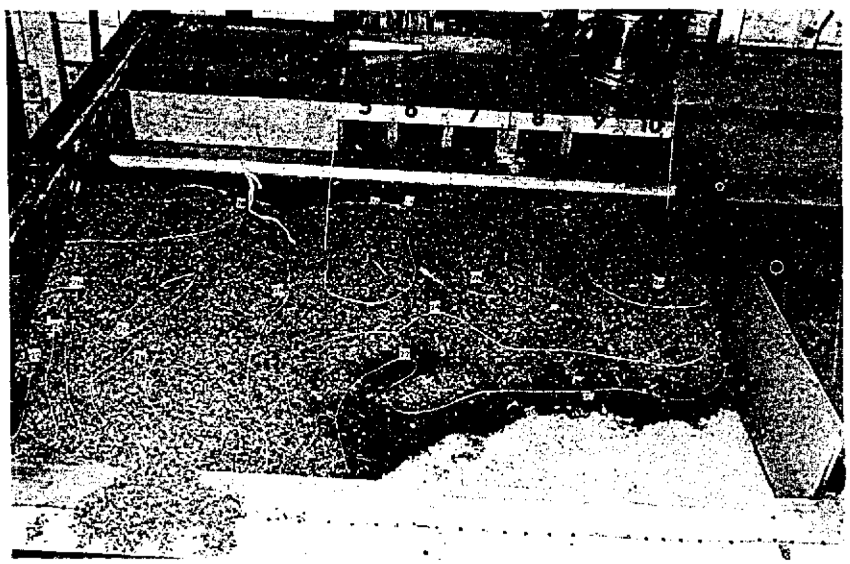
JACKSON LAKE DAM
BAFFLE BLOCK STUDY

Resulting Scour Patterns
from 2,000 cfs (56.634 m^3/sec) Discharge
1:15 Model

FIGURE 7



A. Baffle blocks on apron. Photo P17-D-66286

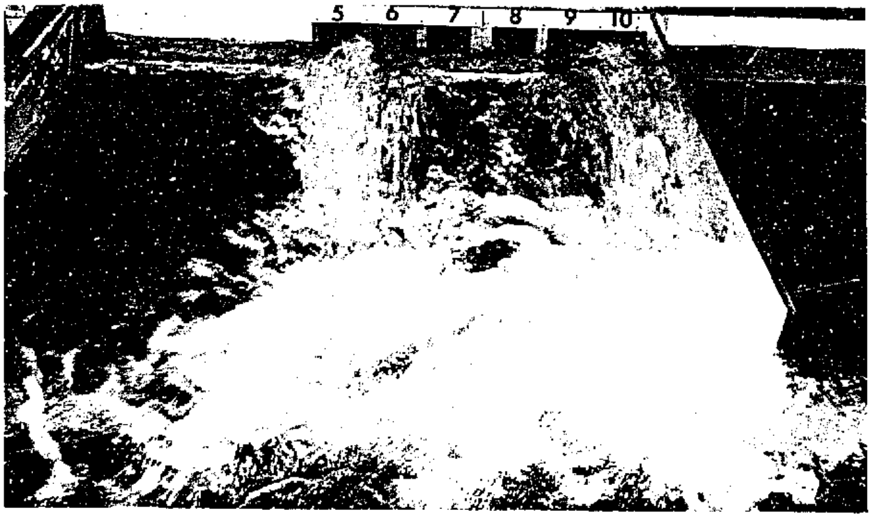


B. End sill on apron. Photo P17-D-66287

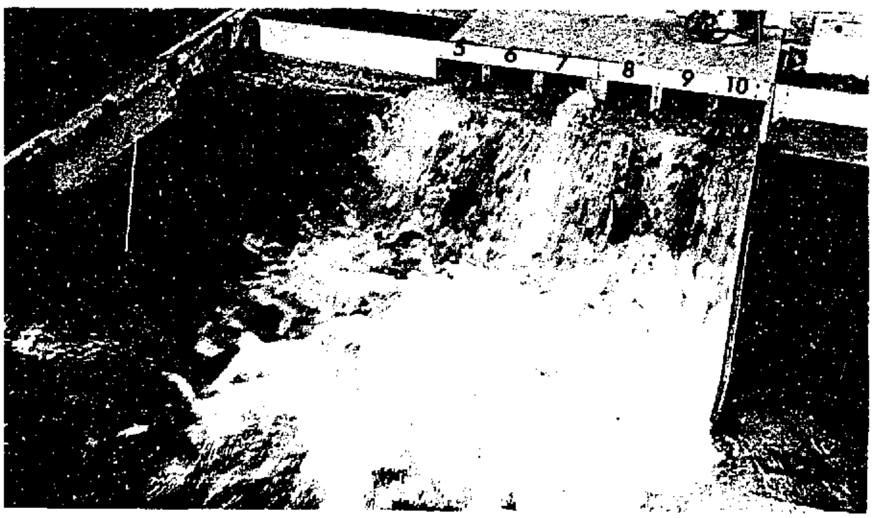
JACKSON LAKE DAM
BAFFLE BLOCK STUDY

Resulting Scour Patterns
from 3,500 cfs (99.109 m^3/sec) Discharge
1:15 Model

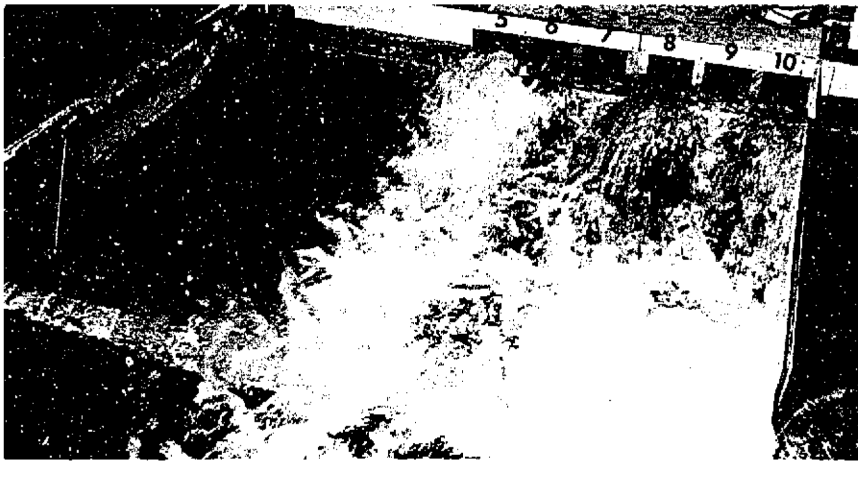
FIGURE 8



A. Sluices 5, 6, 9, and 10.
Photo P17-D-66288



B. Sluices 5, 7, 8, and 10.
Photo P17-D-66289

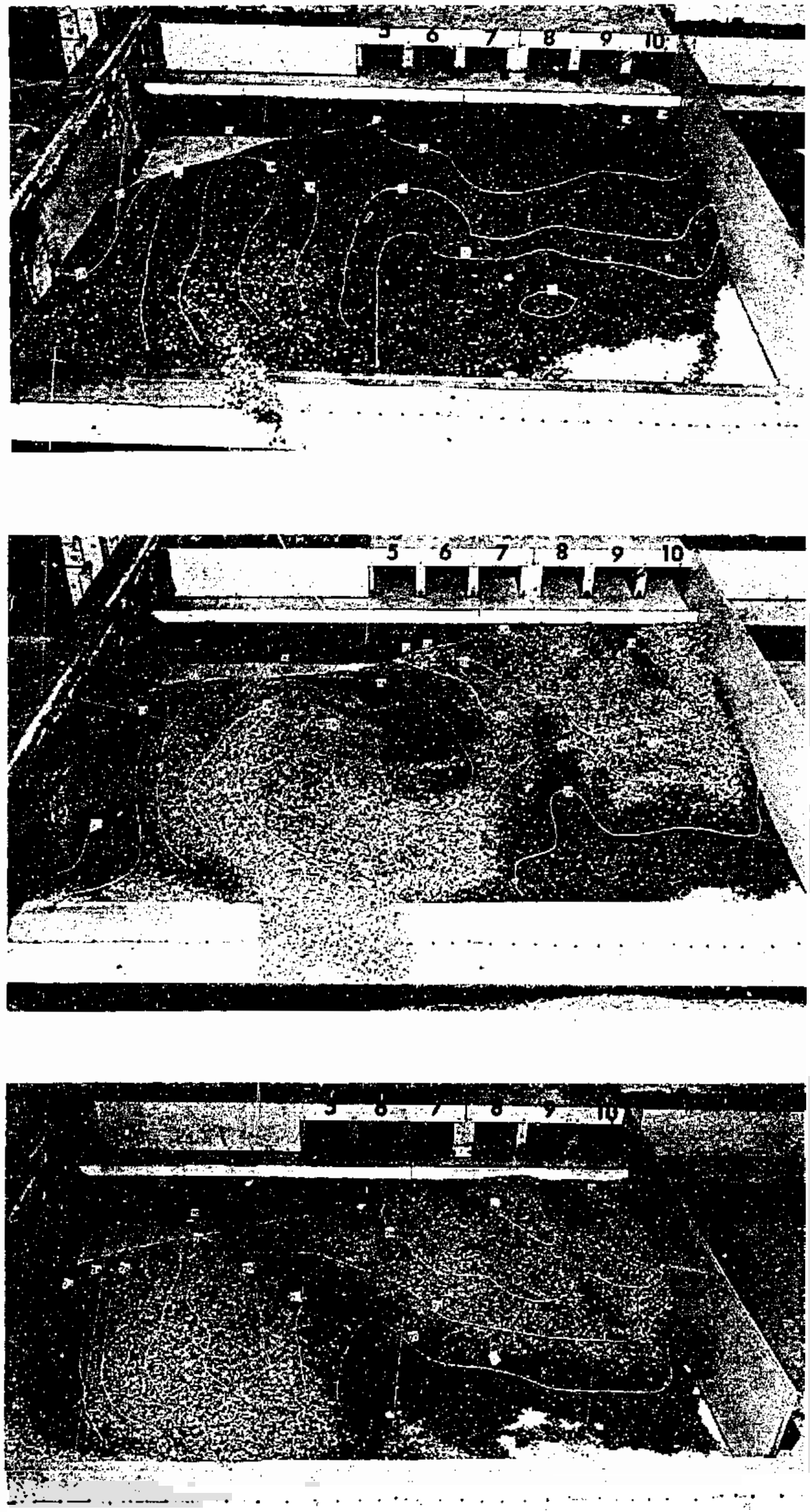


C. Sluices 5, 6, 8, and 10.
Photo P17-D-66290

JACKSON LAKE DAM
BAFFLE BLOCK STUDY

Various Operating Sluice
Arrangements with End Sill
Q = 4,500 cfs (127.426 m^3/sec)
1:15 Model

FIGURE 9



A. Sluices 5, 6, 9, and 10.
Photo P17-D-66291

B. Sluices 5, 7, 8, and 10.
Photo P17-D-66292

C. Sluices 5, 6, 8, and 10.
Photo P17-D-66293

JACKSON LAKE DAM
BAFFLE BLOCK STUDY

Resulting Scour Patterns
from 4,500 cfs (127.426 m^3/sec) Discharge
1:15 Model

7-1750 (1-70)
Bureau of Reclamation

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, E 380-68) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given in 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.

Where approximate or nominal English units are used to express a value or range of values, the converted metric units in parentheses are also approximate or nominal. Where precise English units are used, the converted metric units are expressed as equally significant values.

Table I

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*	Square centimeters
	0.092903	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.)	946.358*	Cubic centimeters
	0.946331*	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

Multiply	By	To obtain
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)	0.092903*	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

ABSTRACT

Model studies of the Jackson Lake Dam sluice outlets were conducted to determine the effectiveness of the existing baffle blocks. Tests were run without baffle blocks, with bàffle blocks, and with an end sill. Evaluation of the various configurations was based on scour patterns resulting from each test. Tests without baffle blocks resulted in a prohibitive scour pattern. The end sill yielded a slight improvement in the scour pattern over that of the existing baffle blocks. Sluice operating arrangements were suggested.

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DESCRIPTORS—/ *scour/ discharges/ *hydraulic models/ *laboratory tests/ sluices/ eddies/ model tests/ sluice gates/ jets/ baffles/ outlet works
IDENTIFIERS—/ Jackson Lake Dam, Wyo/ Minidoka Project, Idaho/ energy dissipators

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