Sluice boxes and riffles

Sluice boxes were laid on bedrock at the most of the mines being operated in 1932. At a few, where high channels were being worked, cuts had been run to bedrock to permit an adequate grade for the sluices. In one mine, a tunnel was used.

Individual boxes were 12 feet long at the majority of places. In a few districts 16-foot boxes were preferred, and occasionally a 10- or 14-foot box was used. The length of the sluice at various mines ranged from 32 to 5,000 feet. The long sluices generally are used only when they are necessary as tailraces. The width of sluice boxes at these mines ranged from 12 to 60 inches. Data on sluice boxes and riffles at the principal hydraulic mines being operated in 1932 are given in table 11. It will be noted from this table that the extreme range in the grade of boxes was from 1/8 inch to 1 1/2 inches to the foot (1.0 to 12.5 percent). The usual range was from 1/4 to 3/4 inch to the foot (2.1 to 6.2 percent).

Riffles serve a twofold purpose, they protect the bottom of the sluice and catch the gold. Both strength and wearing qualities are required in large-scale hydraulic operations where boulders up to a ton in weight may be put through the boxes. Wooden blocks, rails, rock paving, and iron castings, in the order named, were used at the larger mines operated in 1932. When the service was not so severe, poles, angle iron, and Hungarian-type riffles were used. The Hungarian riffles usually were made of wood and were protected from wear on top by strap iron. The kind, size, and spacings of riffles used at the mines visited in 1932 are shown in table 11.

At all mines most of the gold was caught in the first few boxes of the sluice. The top boxes were cleaned up twice a season, monthly, weekly, or even oftener. In long sluices the lower boxes were cleaned only at the end of the season or when repairs were needed. At the time of the general clean-up worn riffles were replaced and the sluices repaired if necessary. Quicksilver was used in the sluices at the largest mines, but at the majority it was used only in cleaning up.

Although the sluice is an efficient gold-saving device some gold gets away, especially if the gold is very fine and the gravel carries a relatively large proportion of black sand. To further recover the gold, undercurrents were used at 10 mines listed. The term "undercurrent" in placer mining is used to designate a device for catching the gold contained in the fine material drawn out through a grizzly in the bottom of the sluice. The undercurrent usually is placed near the lower end of the sluice. At most mines it is not possible to draw all of the material small enough to go through the grizzly to the undercurrent, as not enough water would be left in the sluice to dispose of the coarse material. The quantity drawn off is controlled by the area of the grizzly and the openings between the bars. As shown in table 11, the grizzly bars are 1/8, 1/4, 3/8, 3/4, or 1 1/4 inches apart. Undercurrent boxes, or tables as they are sometimes called, are relatively wide to permit a shallow depth of the sands.

The same type of riffle generally is used on undercurrents as in sluices where a screened product is treated. As shown in table 11, Hungarian riffles, usually similar to those used on dredges, were favored. Steel matting or wire screen over burlap was used at two mines; planks with holes bored in them, angle iron, and stone paving were used at one mine each; and a variety of riffles was used at another mine (Salyer). Quicksilver was used on undercurrents at nearly all of them. An important function of an undercurrent in placers where quicksilver is used in the main sluice is to catch quicksilver or balls of amalgam that may get away in the sluice. As much as 10 percent of the recovered gold may be saved on the undercurrent, but in most places less than 5 percent is so obtained. At three mines where an estimate was made, 3, 5, and 8 percent, respectively, of the total gold recovered was saved on the undercurrent. At two places so little gold reached the undercurrents that they were not cleaned up at the end of the 1932 season.

Sluice boxes and riffles are discussed further under the general section Sluice Boxes and Riffles. The methods of cleaning up boxes also are described.

Hydraulic Mines Operated In 1932

The mines described in the following pages were visited by the authors in June and July 1932. A few other properties were inspected, but as no operating data could be obtained they are not included; with few exceptions they were unimportant, and the practices followed were similar to those at neighboring mines which are described. Two additional mines, the Round Mountain and the Eldorado, that were operated in 1931, are included.

General and operating data concerning these mines are given in tables 8 to 13, inclusive. A mine in British Columbia not visited by the authors is described in the text.

As already stated, hydraulic mines are placed in three groups: (1) Mines without elevators or pumps, (2) mines with Ruble or hydraulic elevators or both, and (3) mines where water for piping and sluicing is pumped. Within each group the operations are further divided according to States.

Mines without elevators

California

Senger.- M. A. Senger, with one man, operated a small mine near Weaverville in the summer of 1932. The deposit was a 6-foot stratum of recent gravel overlying the famous La Grange Channel at the edge of the old workings. The gravel contained a large percentage of boulders and tree stumps. Some small timber had to be cleared off before the gravel could be worked. The false bedrock (top of La Grange Channel) was relatively steep (2 inches to the foot), which facilitated piping boulders to the sluice boxes. Boulders too large to go through the 36-inch sluice were first blasted or broken by hand. Water under a head of 225 feet was obtained from the old La Grange ditch lines; a 4 1/4-inch nozzle was used. Between 30 and 50 cubic yards was handled per day, depending upon the quantity of boulders to be broken. The operating cost was 20 cents per cubic yard. (See table 12.)

Elephant.- The Elephant mine at Volcano was worked under lease during the 1932 season. The gravel ranged from 1 1/2 to 3 feet deep and was overlain by about 45 feet of white, tough, volcanic ash. The ash was drilled by hand augers and blasted. Then it was partly broken up with picks and washed away by the giant. After the ash was removed the gravel was cut by the stream from the giant with a 3-inch nozzle and swept through a race into a sluice consisting of two 16-foot boxes with Hungarian riffles. About 175 miner's inches of water under a 115-foot head was available for 4 hours each day. The tailings were run into a settling basin formed by an earth-filled dam with a concrete spillway outlet. The ditch and pipe lines were in place and were used in early workings in the vicinity. About 62 cubic yards was washed per day or 20 1/2 cubic yards per man-shift. The operating cost of washing the gravel and overburden was 22 cents per yard.

Horton Gulch.- J. O. McBroom operated the Horton Gulch placers on the South Fork of the Salmon River near Cecilville. The 1932 season extended from January 1 to April 11. The gravel was fairly tight. The grade of bedrock was 1 inch to the foot. One giant with a 5-inch nozzle, working under a 65-foot head, was used for both cutting and sweeping the gravel into the sluice boxes. About 30 inches additional by-wash water was used for moving the gravel through the sluice which consisted of three 12-foot boxes 24 inches wide. The riffles were hard boulders hand-shaped to make a pavement 7 to 10 inches thick. An undercurrent was

TABLE 11 - Sluice boxes and riffles at eastern hydraulic mines, 1932 - Continued

Mine	Water through sluice, miner's inches	Duty of water: cu.yd. of gravel per 24 hrs. per miner's inch	Sluice boxes					Riffles							
			Width inches	Depth, inches	Total length, feet	Grade		Type	Width, inches	Height, inches	Length		Center to center, inches	Point at which quicksilver used	Under-currents
						Inches per foot	Per-cent				Ft.	In.			
Diamond City	900	.6	32	36	2,700	1/3	2.8	Pole	5	5	6	0	6 1/2	None	0
Superior			48	60	5,000	11/48	1.9	Wooden blocks		7				First boxes	0
Hockensmith	150	1.6	18	18	600	9/24 to 2/3	3.1 to 5.5	Poles	4	4	2	6	5	None	0
Golden Rule			30		160	3/4	6.2	2 by 6's	2	6	2	0	4 2/7	First boxes	0
								Poles	5	5	12	0	6		
Fortune			26	30	72	2/3	5.5	Rails	1 3/16	2 3/8	12	0	4 1/2	do.	0
Dodman and Weston	400	.8	28	18	132			Cross strips	2	4	2	4	4 3/4	None	0
Round Mountain	400		36	36	5,000	1/3	2.8	Rails	2 3/4	2 3/4	12	0	4 1/2	First boxes	0
Redding Creek	1,200	.5	48		48	3/4	6.2	Hungarian	2	4	4	0	4 1/2	do.	0
Browning	900	.7	48		32	7/16	3.6	Wooden cross	2	4	4	0			0
Llano de Oro	1,300		30	24	700	1/8 to 5/16	1 to 2.5	Steel rails			20	0		First boxes	1
			[1] 30	24	180	5/16	2.5								
Platurica	600	.9	32		304	3/8	3.1	Wooden block		6	2	10		do.	1
								Angle iron	4	4					
Davis	240	.5	32	24	72	3/4	6.2	Hungarian	1	1 1/2	2	6	2 1/2	All boxes	0
Gallia	[2] 325		24	24	125	9/24	3.1	Angle iron	2	2	2	0			0
								Rails			10	0			
Lewis	300	1.0	30		95	3/4	6.2	Steel rails			3	0			1
Conners	28	1.7	12	10	90	1 1/2	12.5	Pole	3	3	6	0	4		1
								Hungarian	1 1/4	2	1	0	2 3/4		
Eldorado Bar	350	1.4	30	36	400	1/4	2.1	Iron	3	1/2	16	0	4 1/2	None	1
								Wooden blocks	4	4	4	0	4		
Old Garden Gulch	400	.4	30		96	3/4	6.2	Angle iron	2	2	2	6	4	First boxes	0

1 In pit.

2 Box in pit between Ruble elevator and hydraulic elevator.

TABLE 11.- Sluice boxes and riffles at western hydraulic mines, 1932

Mine	Water through sluice, miner's inches	Duty of water: cu.yd. of gravel per 24 hrs. per miner's inch	Sluice boxes: Width, inches	Depth, inches	Total length, feet	Grade: Inches per foot	Grade: Per-cent	Riffles: Type	Width, inches	Height, inches	Length: Ft	Length: In	Center to center, inches	Point at which quicksilver used	Under-currents
Sanger	400	0.5	36	24	96	3/4	6.2	Wooden cross	2	6	3	0	4		0
Elephant	175	.8	18	16	32			Hungarian			1	6			0
Horton Gulch	250	.9	24	18	36	1	8.3	Rock paving		6					0
Banner	300		26	24	36	1	8.3	Pole	4	4	2	2	4 1/4		0
Indian Creek	500	3.7	48	36	48	3/4	6.2	Wooden blocks	12	12			12	Undercurrent	1
Salmon River	1,100		36	30	150	7/12	4.9	Rock paving		7				do.	1
Jacobs	480	4.2	48	36	120	3/4	6.2	Wooden blocks							0
Omega Hill	1,500	2.7	48	36	1,700	1/2	4.2	do.		12				First boxes	0
Indian Hill	650		40	40	288	1/2	4.2	Wooden blocks and rock paving	12	12				do.	3
Depot Hill	600	1.0	30	24	3,500	3/14	1.8	Wooden blocks	12 to 24	7			12	do.	0
North Fork Placers	1,300	1.0	48	40	168	1	8.3	Rails		3 1/2	12	0	4 1/4	do.	1
Salyer	2,800	4.3	60	50	350	3/4	6.2	Wooden blocks					18	do.	1
Norton and Nelson	600		20	20	100	3/4	6.2	Hungarian			2	8			0
								Pole			6	0			
Salmon Creek	150	2.6	36	20	180	1 1/4	10.4	Rails	2	2 1/2	10	0	4		0
						1 1/4	10.4	Poles	4	4	6	0	5		
						1	8.3	Hungarian	1 1/2	1 1/2	2	2	3		
Blue Channel	1,200		36		80			do.	2	4	3	0	6 1/2		0
Deep Creek	200	1.3	20	18	300	3/4 to 1 1/2	6.2 to 12.5	Pole	4	4	6	0	15	None	0
Yellowstone Gold	600	5	22	24	500	1/3	2.8	Angle iron	2	1 1/2	1	11	2 3/4	None	0
Virginia City	85	1.4	14.5	18	110	5/12	3.5	Hungarian	2	4	1	2 1/2	8	None	0
								Pole	4	4	6	0	5		
								16-lb. rails	1 3/16	2 3/8	12	0	3		
Henderson No. 1	600	2.0	22	24	120	3/4	6.2	Cast iron	3	1 1/4	4	0	5	None	0
Henderson No. 2	150	4.0	22	24	120	3/4	6.2	do.	3	1 1/4	4	0	5	None	0
Wisconsin Gulch	2,800	.1	44	40	1,900	7/24	2.4	40-lb. rails	1 7/8	3 1/2	30	0	6 1/4	None	0
Stemwinder	150	1.3	24	18	240	7/12	4.8	Pole	4	4	5	6		None	0

washed was spent for storing tailings back of a power dam. The charge was reduced from 3 to 2 cents in 1932. Other mines also had tailing-disposal charges in connection with mining operations. The cost of supplies and incidentals usually ranged from 1 to 2 cents. At one mine supplies cost 5 cents per cubic yard, but a power shovel was used in connection with hydraulicking. Timber for boxes is the main item of operating supplies at most hydraulic mines. Explosives at one mine - Golden Rule - cost 2 cents and at another 1 cent per cubic yard washed. At most mines where explosives were used, however, the cost of explosives was well under 1 cent per cubic yard. The cost for supervision ranged from 0.3 to 10 cents at mines where supervising officials were employed. Unless the gravel is unusually rich, the salary of a nonworking supervisor at most small hydraulic mines raises the operating cost to a prohibitive figure.

Operating costs at mines where elevators were used are as follows:

Two mines with Ruble elevators, 19 and 6 cents per cubic yard.

Three mines with hydraulic elevators, 8, 8, and 27 cents per cubic yard.

Two mines with both Ruble and hydraulic elevators, 17 and 10 cents per cubic yard.

At four mines where water was pumped for hydraulicking the operating costs were 93, 29, 38, and 28 cents per cubic yard. At two of these where electric power was used, the power cost 15 cents with a 200-foot lift and 21 cents with a 100-foot lift; in the second mine half the water was used in a hydraulic elevator. In both mines a 40-pound pressure was maintained on the nozzles. At the third mine, where gasoline engines were used, the fuel cost for a 225-foot lift was 22 cents per cubic yard. A 65-pound working pressure was maintained at the nozzle. At the fourth mine water for hydraulicking was pumped by steam at a cost of 5 cents per cubic yard. Fuel for a gravel pump cost 4.9 cents per cubic yard.

Sufficient data are not available to calculate total costs at any of the mines. In all but a few mines old ditch and pipe lines were used, which were charged off years ago. Depreciation or amortization charges could not be figured, as the quantity of gravel to be washed was known at only a few mines.

SLUICE BOXES AND RIFFLES (GENERAL)

The sluice box serves a double purpose in placer mining; it collects the gold or other heavy minerals sought within the riffles of the sluice and conveys the washed material to a dumping ground. It is an efficient gold saver and is universally used in hydraulicking and ground-sluicing. The principle of the riffled sluice is used for recovering most of the gold on dredges and in other forms of placer mining where the gravels are excavated mechanically.

Other types of gold savers have not proved generally successful in placer mining, although as an auxiliary method and under special conditions some of these gold-saving devices have been found useful. This subject is further discussed in a subsequent paper under the heading of Excavation of Placer Gravels by Power Equipment.[29]

Sluices are built in accordance with the service to be demanded of them. Riffles are of varied forms and are made of different materials. Although the form of riffle is chosen largely to fit particular conditions custom in various districts and materials at hand have a bearing upon the practices followed.

The following discussion has a general application and is not confined to any region or method of mining.

29 Gardner, E. D., and Johnson, C. H., Placer Mining in Western United States: Part III. - Dredging and Other Forms of Mechanical Handling of Placer Gravels, and Drift Mining: Inf. Circ. 6788, Bureau of Mines, 1934.

Sluice Boxes

Construction

Sluice boxes are rectangular in section and are nearly always built of lumber; steel or iron sluices, however, were used at a few washing plants operated in 1932.

The construction of a wooden sluice box depends somewhat upon the size and service expected of the box; a number of types, however, may be used satisfactorily. Common types of construction for large and small boxes are illustrated in figure 13.

The important features in design are sturdiness and simplicity of construction. Large flumes may have to withstand severe battering and vibration from the passage of heavy boulders, hence they must be strongly constructed and well braced. In small flumes this feature is less important, but the use of lighter lumber increases the difficulties of maintenance and prevention of leaks.

The bottom of a narrow sluice should be a single plank if lumber of the desired width is obtainable; for wider boxes two or more bottom planks must be used. The bottom joints may be made tight by the use of soft-pine splines, by batten strips nailed on the outside, or by caulking with oakum or other material. Bowie[30] recommends half-seasoned lumber as most suitable for the construction of boxes. Where local timber is used it is common practice to cut the plank during the dry season or before snow is off the ground. It is not customary to use surfaced lumber for boxes, although a smooth bottom facilitates the clean-up. The lumber should be clear and of uniform size.

For any but small, temporary installations the sides of sluice boxes should be lined with a wearing surface of rough lumber or sheet iron. Otherwise the entire box must be replaced when the sides are worn out. Board lining is easier to place and replace than sheet iron. In early Californian practice some of the side linings were made of wide, thin blocks nailed on so as to present the endgrain to the wear. Worn iron or steel riffles are used for side lining at some places. Usually only the lower half or third of the side of the box needs this protection, and a single 2-inch board may serve not only for lining but as a cleat to hold down the riffles. False bottoms of planed or rough boards may be used to save wear on the box proper.

Each box should rest on three or four sills, equally spaced. The sills and upright members at the ends of the box serve as battens to prevent leakage at joints. The practice of tapering the box enough to permit a telescope joint is very convenient in small sluices, especially if the boxes must be moved occasionally. Small, three-board boxes may be braced with ties across the top, although this hampers shoveling and clean-up operations. Larger boxes should be braced externally from the ends of the sills, as illustrated in figure 13, A and B. Sills should be weighted with rocks to check any tendency of the sluice to rise. If the sluice is placed in a bedrock or other cut, water under it or at the sides has a strong lifting effect. Moreover, the vibration caused by boulders rolling through the sluice permits fine gravel to be washed under the sills placed on the ground.

The following table shows the price of lumber suitable for building sluices at various places in the summer of 1932:

30 Bowie, A. J., Hydraulic Mining in California: Van Nostrand Co., New York, 3d ed., 1889, p. 220.

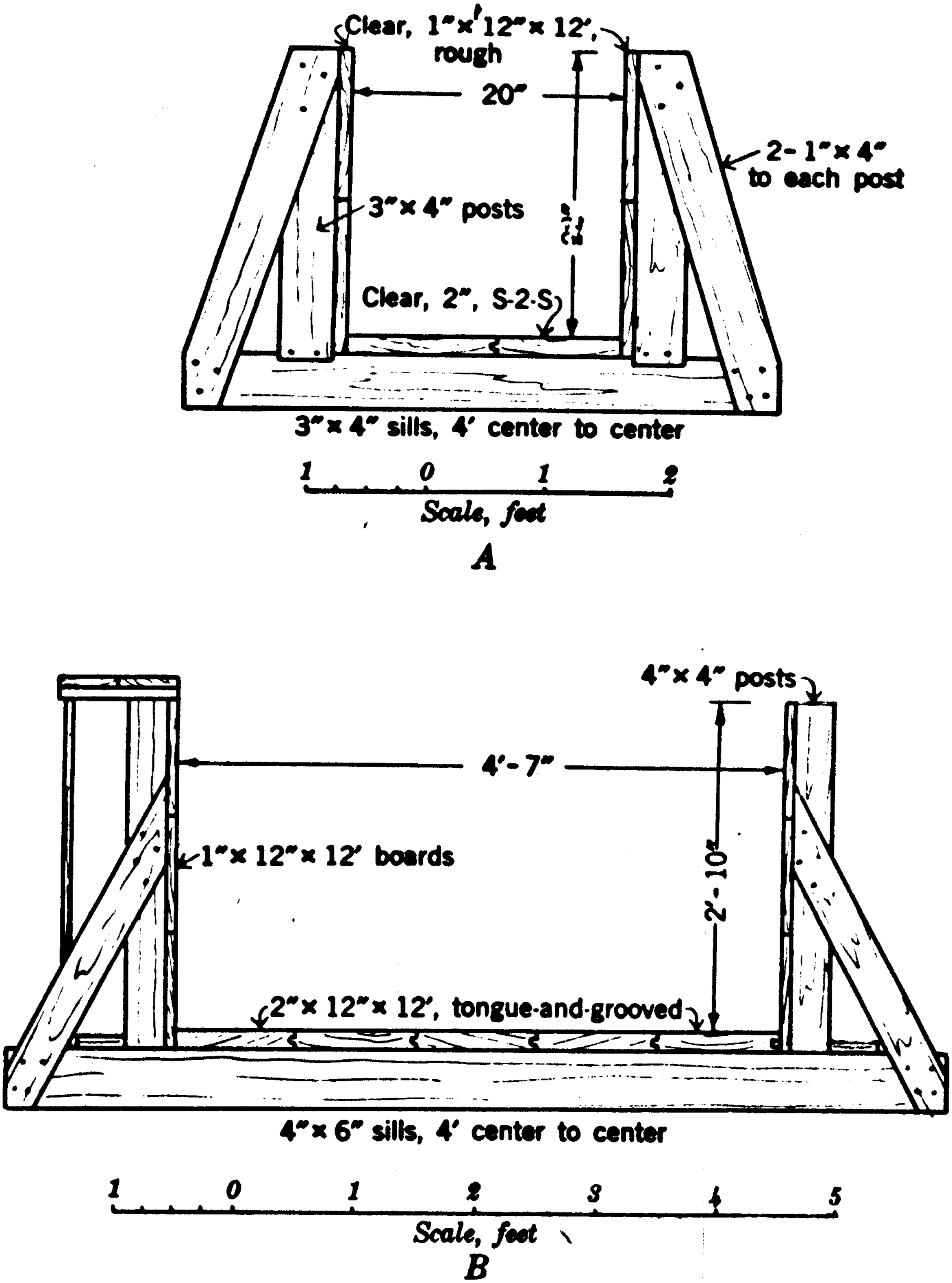

Figure 13.—Sluice-box construction: *A*, Twenty-inch box at Henderson mine, Gold Creek, Mont.; *B*, five-foot sluice box.

	Price per 1,000 board feet
Oregon House, Calif.	$25.00
Sawyers Bar, Calif.	30.00
Waldo, Oreg. (cutting and sawing only)	8.00
Wenatchee, Wash.	20.00
Emigrant, Mont.	20.00
Townsend, Mont.:	
1- by 12-foot	28.00
2- by 16-foot	35.00
Therma, N. Mex.	22.00

As mentioned, the side lining plank may serve as a cleat under which the riffle sections can be wedged to the bottom of the sluice. Otherwise some other provision must be made as the riffles must be held securely. In small boxes it is customary to lay long, narrow boards on edge on top of the riffles and against the sides of the sluice. These boards are wedged down tightly under cleats nailed permanently to the sides of the box. The practice of nailing riffles to the bottom of the box, or using any device that requires driving nails in the bottom or sides, should be avoided as it results in leaks and eventually damages both sluice and riffles. Wooden blocks are the most difficult to secure in place but can be held by the method described in the following section. Rock pavement depends on its weight, on being packed tightly, and sometimes on the slight downstream tilt of the individual stones to resist the shifting action of the current.

Maintenance

Maintenance work on sluice boxes consists chiefly in alining and bringing to grade any boxes that have moved out of position, replacing linings, and plugging leaks. Attention to this work at clean-up time will be repaid by greater capacity and freedom from break-downs when the water again is turned into the sluice.

Size

As previously shown, sluice boxes seldom are built less than 10 inches wide for strictly mining purposes. Eight-inch boxes, however, may be used in sampling or cleaning up. The quantity of water, with its accompanying load of gravel, that will run through a sluice of a given size depends upon a number of factors. The practice at the majority of about 75 hydraulic and ground-sluice mines visited in the preparation of this paper indicates that the carrying capacities of sluices of various widths are within the following limits:

Width of box, inches	Miner's inches of water	
	From	To
12	25	100
18	100	300
24	200	600
36	500	1,300
48 to 60	1,000	3,000

These limits probably represent good practice.

More trouble is experienced from clogging of boxes that are too wide, because the depth and velocity of water are insufficient, than from failure of boxes to carry their load because they are too narrow.

The current velocities required to transport different sizes of material have been studied; works of various authorities are cited by Gilbert.[31] The following table is based chiefly on Dubuat's figures for competent velocity; the figures are adjusted to approximate mean velocity instead of bed velocity. The last three figures are taken from Van Wagenen.[32]

Size of material moved	Mean velocity, approximate feet per second
Sand:	
Fine	0.5
Coarse	1.0
Gravel:	
Fine	1.5
1-inch	2.5
Egg-size	4.0
Boulders:	
3- and 4-inch	5.3
6- to 8-inch	6.7
12- to 18-inch	10.0

Well-rounded pebbles are easier to move than angular ones, and rock of low specific gravity is appreciably easier to wash than heavy, dense rock such as greenstone or basalt.

Gold has a better opportunity to settle and be caught in riffles in a wide, shallow stream than in a deeper and narrower stream of the same volume; the wider sluice, however, usually must be set on a steeper grade.

Small- or medium-size boxes generally are roughly square in cross-section; large boxes usually are one half to two thirds as deep as they are wide. The water in a sluice should always be more than deep enough to cover the largest boulder that may be sent through. In practice, the depth of the stream in the main sluice at hydraulic mines usually is a fifth to a half the width of the box so as to prevent spills if the box is temporarily plugged by boulders or sand. Where screened gravel is being washed, as in undercurrents or on dredges, wide and shallow streams are necessary for the recovery of fine gold. In "booming" operations the boxes usually are run full in order to handle the relatively large volumes of water that flow for short periods only, and the sluices commonly are about as deep as they are wide. It would be desirable but impracticable to decrease the depth of water by using wider sluices, as flows of 5,000 to 10,000 miner's inches are not unusual when the gate of the reservoir suddenly is opened wide.

Grade

Usually the grade of the sluice depends upon the slope and contour of the bedrock. If the gradient of bedrock, however, is to low to permit sufficient fall for the sluice, cuts or tunnels may be run in the bedrock to overcome this difficulty. Very short sluices of only

31 Gilbert, G. K., The Transportation of Debris by Running Water: U.S. Geol. Survey, Prof. Paper 86, 1914, p. 216.
32 Van Wagenen, T. F., Manual of Hydraulic Mining: Van Nostrand Co., New York, 1880, p. 88.

1 or 2 boxes sometimes are set nearly flat where there is a drop at the end of the box, the gravel being forced through the sluice by the initial velocity and the head of water in the pit.

The opinion of most operators is that about 6 inches in 12 feet is the best grade for average conditions. As shown, grades as flat as 3 inches in 16 feet can be used but only at great loss of capacity. At the Depot Hill mine, where a grade of 3 inches in 14 feet is used, all rocks over 5 or 6 inches in diameter must be left in the pit. Because of the greater friction and the consequent lowering of velocity, steeper grades are needed for small sluices than for large ones; some operators favor grades of 12 inches to a 12-foot box. For maximum gold-saving efficiency, as well as for economy in dump room, grades should be as flat as possible without lowering the velocity to such an extent that the riffles pack with sand. Any increase in slope from that adjustment will increase the capacity of the sluice, increase the wear on the sluice, and decrease the efficiency of the riffles, resulting in gold losses if carried to extremes or if the gold is very fine. If water is scarce, gold recovery may well be sacrificed to capacity. Bowie[33] states that grades of 10 to 24 inches were used in some Forest Hill Divide (Calif.) mines for this reason. Increasing the proportion of water to solids decreases the tendency of riffles to pack with sand.

Sluice capacity increases with grade but more rapidly; that is, doubling the grade of sluice boxes will more than double the quantity of gravel that can be put through the boxes by a given flow of water. The absolute increase cannot be predicted closely as coarseness of gravel, velocity, and shape of the box appear to have some bearing on the relation of capacity to slope. For instance, Bowie[34] cites a mine at which changing the grade from 3 to 3 1/2 inches in 16 feet increased the quantity of gravel sluiced through the same boxes with the same flow of water by about one third.

The established grade should not be decreased anywhere along a sluice, otherwise gravel may accumulate where the current loses velocity. If the water and gravel, however, enter the first box with considerable speed, say, from the discharge of a hydraulic elevator, the first boxes may be placed on less than the regular grade. Bends or curves are undesirable as they complicate construction and induce clogging and running over. When a curve is unavoidable it should be as gradual as possible, the outside of the sluice should be elevated a fraction of an inch, and the grade should be increased perhaps an inch per box at and immediately below the curve. Similar rules apply to turn-outs or branches, and drops of 3 or 4 inches should be provided at junctions to check the deposition of gravel at these points. Such drops occasionally are inserted in straight sluices if the grade is available, particularly if the gravel is a difficult one to wash or if heavy sand tends to settle to the bottom. A drop of even a few inches from one box to the next has a disintegrating effect and mixes the material passing through the sluice, thus assisting gold recovery. At one place where drops were provided at intervals between different types of riffles, 25 percent of the gold recovered in the sluice was found at the drops.[35]

Riffles

Theory of gold-saving by riffles

The function of riffles is to hold back the gold particles that have settled to the bottom of a flowing stream of water and gravel. Any "dead" space in the bottom of a sluice

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33 Bowie, A. J., A Practical Treatise on Hydraulic Mining in California: Van Nostrand Co., New York, 3d ed., 1889, p. 220.

34 Bowie, A. J., work cited, p. 208.

35 Theller, J. N., Hydraulicking on the Klamath River: Min. and Sci. Press, vol. 108, Mar. 28, 1914, pp. 523-526.

box, where there is no current, fills quickly with sand and thereupon loses most of its value as a gold saver, unless the sand remains loose enough to permit gold to settle into it; therefore, the shape of riffles is important, regardless of the fact that under some conditions, as with coarse gold and free-washing gravel, all forms of riffles are almost equally efficient. The riffle should be shaped so as to agitate the passing current and produce a moderately strong eddy or "boil" in the space behind or below it, thus preventing sand from settling there and at the same time holding the gold from sliding farther down the sluice. In other words, riffles, for maximum efficiency, should provide a rough bottom that will disturb the even flow of sand and gravel, will retain the gold, and will not become packed with sand. Where grade is lacking the riffles must be relatively smooth, so as not to retard the current unduly; under these conditions the sluice must be long enough to compensate for the loss in gold-saving efficiency of the individual riffles.

Natural stream beds act as gold-saving sluices, not because they are particularly efficient as such but because most gold is "hard to lose" and the streams are long.

Types of riffles

Riffles, of course, should be designed so as to save the gold under the existing conditions. They should also be cheap, durable, and easy to place and remove. Not all these qualities are found in any one type.

Sluice-box riffles may be classified roughly as transverse, longitudinal, block, blanket, and miscellaneous roughly surfaced ones, or, according to material, as wood block, pole, stone, cast iron, rail, angle iron, fabric, and miscellaneous. Usually more than one type of riffle is used, although in California very long sluices have been paved entirely with wood-block riffles, and on dredges the type illustrated in figure 14, A, is used almost exclusively.

Of about 80 hydraulic, ground-sluice, and mechanically worked placer mines visited in 1932 by the authors, approximately 25 percent used riffles of the transverse variety, loosely termed "Hungarian", consisting generally of wooden crossbars fixed in a frame and sometimes capped with iron straps. About 20 percent used the longitudinal pole type, 15 percent wooden blocks, and 15 percent rails, the last being placed crosswise or lengthwise. Angle-iron riffles, wire-mesh screen or expanded metal on carpet, blankets, or burlap, rock paving, and cast-iron sections together made up the remaining 25 percent. The only general rule observed was that the size of the riffles was roughly proportional to the size of the material to be handled and that for fine material, particularly the screened gravel washed in most of the mechanically operated plants, the dredge-type riffle found most favor.

For a small or medium-size sluice (if lumber is costly and a plentiful supply of small timber, such as the lodge-pole pine so common in many Western States, is available) peeled pole riffles (fig. 14 B and C) are perhaps the most economical and satisfactory of the various types. Their construction is evident from the drawing. Those of transverse variety may have a somewhat higher gold-saving efficiency, but undoubtedly they retard the current more and wear out faster. Poles 2 to 6 inches in diameter may be used, spaced 1 or 2 inches apart. Such riffles are cheap but wear out rapidly. The sections should be a third or half the box length for convenience and 1 or 2 inches narrower than the sluice. At the Golden Rule mine 6-inch pole riffles had to be replaced every 10 days or after each 1,200 cubic yards had been sluiced. The sluice was 30 inches wide and had a grade of 8 inches in 12 feet. At other mines poles last several times as long.

If sawed lumber can be obtained cheaply, riffles similar to the one described may be made of 1- by 2-, 2- by 2-, or 2- by 4-inch material, as shown in figure 14, D and E. The top surfaces of the riffles may be plated with strap iron (fig. 14, F and G). Transverse