WATER POWER POSSIBILITIES OF THE RED CEDAR RIVER

Thesis for the Degree of B. S.
MICHIGAN STATE COLLEGE

George R. Grantham

1938

WATER POWER POSSIBILITIES
OF THE
RED CEDAR RIVER

A Thesis Submitted to

The Faculty of the

MICHIGAN STATE COLLEGE

OF

AGRICULTURE AND APPLIED SCIENCE

BY

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Candidate for the Degree of

Bachelor of Science

June 1938

PREFACE

The increasing demand for power in all industries, its continually growing uses in the home, and with the increasing fuel cost, have made the public look into water power development. As a consequence large projects of power developement are being planned. It is evident that all water power commercially available should be utilised and with this in mind I would like to find out what possibilities our own Red Cedar River has as a power source. Only preliminary investigations will be studied in this thesis to find out if power from the river is economical.

It is fitting that acknowledgement be given those persons who gave valuable assistance and information: to John M. Patriarche, a classmate, who assisted in the surveying work; to Professor C.M. Cade who gave valuable suggestions; to the personnel of the Lansing office of the U.S. Geological Survey, Water Supply Bureau, who gave me available floe data; and to Mr. H.K. Barrows whose book "Water Power Engineering" served as a form by which this study was made.

WATER POWER POSSIBILITIES OF THE RED CEDAR RIVER AT EAST LANSING, MICHIGAN.

A. Power Available

The prime essentials of hydro-power are (1) a suitable quantity of water (2) falling through a distance. The energy developed by falling water is used in generating power. Therefore, to compute the power available we must investigate the flow of water and the available head.

1. Flow of Water

The flow of water for the Red Cedar River at East Lansing, Michigan is shown in Table 1. This data was gathered by the U.S. Geological Survey, Bureau of Water Supply, and the U.S. Weather Bureau in conjunction with Michigan State College. Only approximately eight years of daily flow records are available, while crest flows are available for twenty five years. During the eight years of daily records, however, we have records for 1934 which was a very dry year, having only 21.00 inches of precipitation that year. That deficiency in precipitation is exceeded only by two years in 63 years of records. We also have records for years in which the precipitation was running close to normal. It is assumed, taking into account of the facts stated above, that the flow data listed in Table 1 are average flows and are to be used to give satisfactory results.

Twenty five years of records show that the maximum flow was 5200 c.f.s. on March 15, 1918. The minimum flow was 3 cfs

AVERAGE FLOW CFS

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1902	—	—	—	—	—	—	—	—	144	285	223	322
1903	571	959	860	143	154	132	172	423	173	152	103	337
1931	—	—	841	623	529	662	[illegible]	144	2[illegible]7	285	661	732
1932	215	222	225	290	330	43	342	399	183	128	199	263
1933	294	[illegible]83	321	669	354	[illegible]	31	302	258	121	818	115
1934	121	453	586	465	654	253	559	60	—	16	18	226
1935	516	674	655	105	142	134	41.8	29	371	245	654	652
1936	519	160	478	212	104	356	167	108	254	49.8	[illegible]5	40
1937	37	147	71.1	811	376	726	134	—	—	—	—	—
Average	[illegible]3	[illegible]99	356	434	195	168	54	43	153	103	108	126
CFS per Sq Mi	.477	.56	1.00	1.22	.55	.473	.152	.12	.43	.29	.304	.353

Average yearly flow - 176 cfs

Minimum flow - 3 cfs on July 31, 1931

Minimum Ave Monthly flow - 559 cfs during July, 1934

Maximum Flow - 5200 cfs March 15, 1918.

occuring July 31, 1931 and the minimum average monthly flow was 5.59 cfs in July, 1934.

Daily river flow records furnished data used in the construction of the flow-duration curve shown as figure 1. The average flow for each day was plotted in order of intensity and the curve was drawn through these points. From this flow duration curve we can determine the amount of primary and secondary power available for a given head.

2. Available Head

It is practical to remove the existing dam (behind the Shops Building on the Campus), to obtain additional head for this power project. The only function of that dam is to stablize the river elevation, and the power dam put in a few hundred feet upstream would serve the same purpose. It is also practical to improve the channel of the river to a point 1600 feet below Farm Lane bridge to provide adequate flow to carry away the tail water. Plans for this channel improvement can be found inside the back cover. From this study we establish the elevation of the dam at 821.1. Using the Manning formula with $n = 0.025$, $s = 0.00017$ (from plans) and a reasonable(up to 400 cfs) flow, we get a depth of 2.80 feet in the channel. For the average flow of 176 cfs, the depth of water is less than two feet. The depth of water is assumed as 2.70 feet in computations for head available.

From the U.S. Geological Survey quadrangle map of Mason quadrangle, the elevation of the headwater was set at 840.00 mean sea datum. It was found that at this level a fair sized pond would be formed without an extreme length of dam. With

the tail elevation established at 823, 8 we find that 16.2 feet of head is available. From this, a reasonable loss of head due to friction through the plant must be deducted. A loss of 1.2 Feet was decided upon from a table on page 166 of "Water Power Engineering" by H.K. Barrows. This leaves an available head of 15.00 feet.

3. Pondage for Equalizing Flow

The possibility of storage to increase flow for the dry months was investigated and was found that to equalize the flow for a whole year a total of 27,900 acre-feet would be needed. This makes any kind of storage out of the question and the matter was immediately dropped and pondage was considered.

The results obtained in Table 2 for pondage were gotten with the method outlined on page 155 of "Water Power Engineering" by H.K. Barrows. By using pondage during the periods of low flow, the flow can be increased . It was decided that for July and August, a ten hour use would be made, for October, November, and December, a fourteen hour use would be made, for January, June, and September, an eighteen hour use, and in February, March, April, and May, the plant could operate 24 hours. This arrangement increases hte flow for periods of use over the continuous flow to quite a marked degree.

By computing the volumes stored during the periods of rest, it was found that the elevation difference due to pondage would be less than 0.7 feet. In fact, it was found

PONDAGE

	Rate of 24 hr. flow	24 hr flow (Acre ft)	Pondage Req'd	Am't used daily	Same (cfs)	Flow (no Pondage)	Total Flow	Pondage Factor	Hours of Use
Jan	173	346	86.6	86.6	57.6	173	230.6	1.33	18
Feb	199	398	None	—	—	—	199	0	24?
Mar	356	712	None	—	—	—	356	0	24
Apr	434	868	None	—	—	—	434	0	24
May	195	390	None	—	—	—	195	0	24
June	168	336	84	84	56	168	224	1.33	18
July	54	108	63	63	75.6	54	129.6	2.40	10
Aug.	43	86	50.2	50.2	60.2	43	103.2	2.40	10
Sept	153	306	76.5	76.5	51	153	204	1.33	18
Oct	103	206	86	86	73.7	103	176.7	1.70	14
Nov	108	216	90	90	77	108	185	1.70	14
Dec	126	252	105	105	90	126	216	1.70	14

that if no water flowed into the reservoir in August and 103.2 cfs (for ten hour day) were taken out each day, the total volume used would be 2666 acre-feet in one month, which would cause a difference of approximately two feet in elevation.

4. Power (see Table 3).

THe flow- duration curve (figure 1) is used in computing the available primary and secondary power. Primary horsepower is the horsepower available at the plant at all times. The effect of pondage on the flow is considered as primary power. The amount of primary power at 80% efficiency is figured at 140 horsepower at times of use. Secondary power is power generated over and above the primary power. The average flow was figured by the use of the planimeter and primary flow subtracted. This figure is 127 cfs which generates 173 horsepower. The total average yearly power is the sum of these primary and secondary horsepowers or 313 horsepower.

Energy in kilowatt-hours generated at 93% efficiency is figured from the power developed multiplied by the time. The monthly kilowatt-hour capacity is shown in Table 3. Primary energy is figured from power developed multiplied by the time and divided by the pondage factor. This results in a total primary energy manufactured yearly and is equal to 86,400 kilowatt-hours. Secondary energy is the energy manufactured besides the primary power and therefore is the total energy developed minus the primary energy.

This total energy available is not near enough to supply the demand of the College. The energy developed , however, can be used to decrease the load already on the steam plant

TABLE III

Average Yearly Output at Shaft
Horsepower at 80% Efficiency

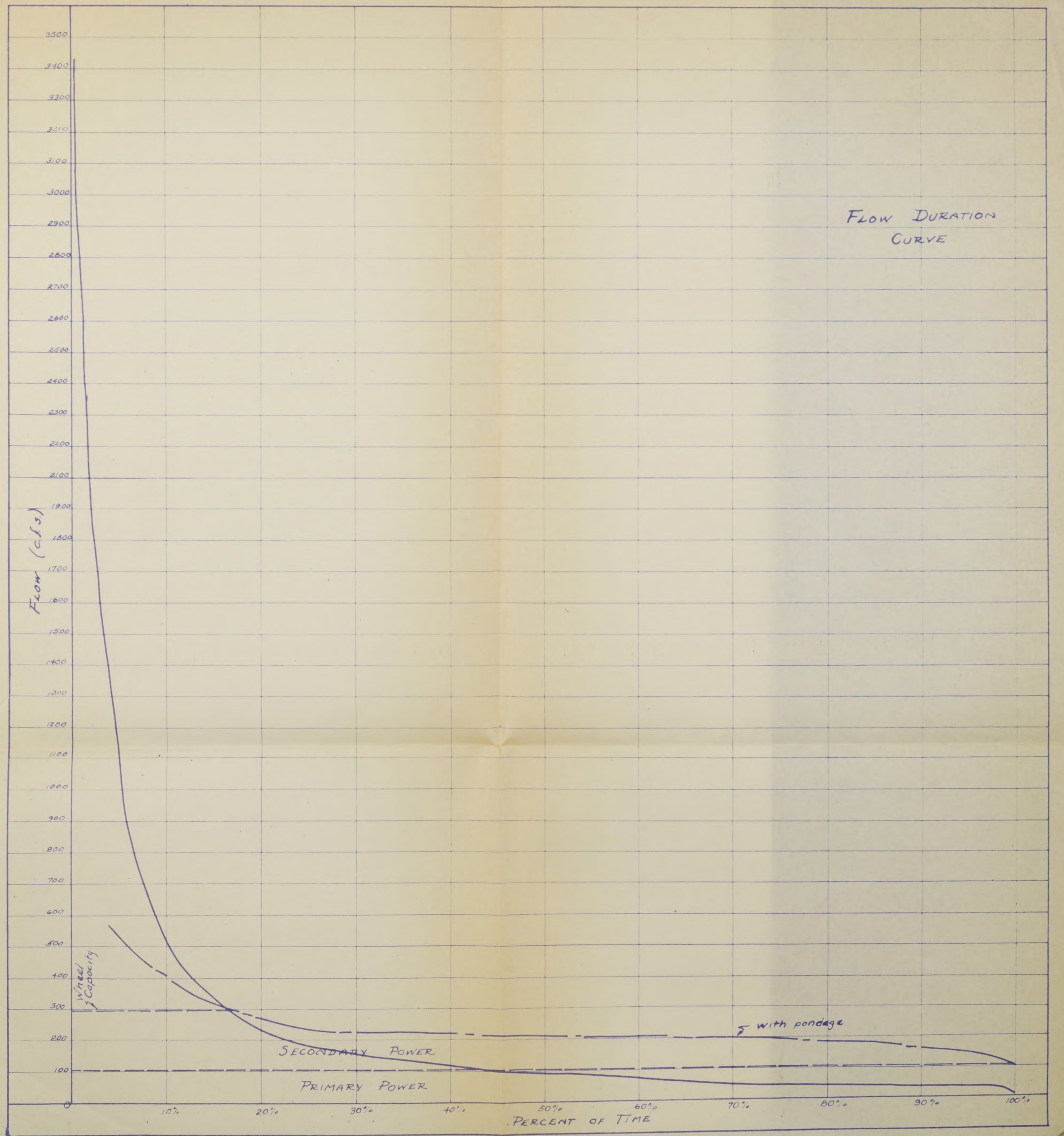
Primary	Secondary	Total
140	173	313

Kilowatt-Hours Yearly at Switchboard
93% Efficiency

Primary	Secondary	Total
86 400	985 700	1 072 100

MONTHLY OUTPUT

	Average Flow cfs	Horsepower 80% eff.	Kilowatts 93% eff.	Hours of Use	Kilowatt Hours
Jan.	173	236	164	558	91 500
Feb	199	271	188	672	126 000
Mar.	290	394	273	745	203 000
April	290	394	273	724	197 000
May	195	266	185	745	138 000
June	168	228	158	542	85 800
July	54	74	51	178	9100
Aug	43	58	40	[illegible]8	7200
Sept.	153	208	144	542	78 200
Oct.	103	140	97	434	42 100
Nov.	108	147	102	422	43000
Dec	126	171	118	434	51200
				Total	1072000


FLOW DURATION CURVE
FLOW (c.f.s.)
PERCENT OF TIME
Wheel Capacity
with pondage
SECONDARY POWER
PRIMARY POWER
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

now in use. There are two ways in which this energy source can be used. First, as a base power source using the steam energy source to furnish the peak load conditions and to supply the that energy needed above the hydro-power source. The second way- to use the hydro-power source to ease the peak load on the steam plant which is used as base power.

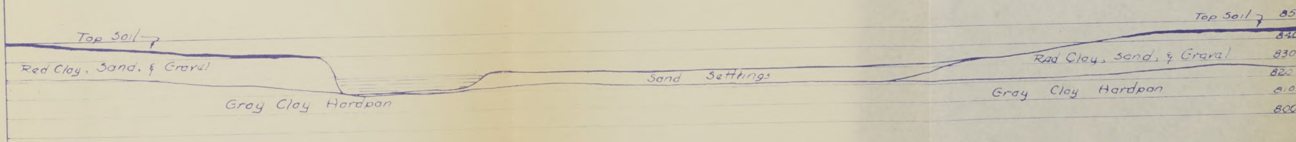
In February, March, April, and May, when the energy is manufactured 24 hours a day, the hydro-power plant could be used as a base supply and the steam plant used as auxiliary to produce peak energy and in the other months during intermittant energy developement, the steam plant could generate the base supply. The hydro-power plant could be used to generate power during the peak hours. In this way fuel costs would be cut.

B. Dam and Plant

1. Dam Design.

Maps and borings show that a dam resting on clay hardpan at elevation 820.00 would have to be 24 feet high to back water up to the predetermined height of 840.00. The earth type dam is the only practical dam which could be used. A typical earth dam was decided upon. A spillway section sufficient to discharge the maximum flows must be included.

The front slope should be 1 on 4 and faced with rip-rap. At a point 28 feet to the upstream side of the center-line a concrete core wall is used. This wall extends out above the water to an elevation of 843.00 and is used as wave protection. The core wall extends down to the clay hardpan and below that there is a wall of sheet piling to



FOUNDATION SOIL CONDITIONS

Borings made with soil auger
Scale 1" = 50'

further cut off seepage.

A twenty foot concrete roadway is constructed on top of the dam. This roadway is to carry traffic now carried by Farm Lane and Farm Lane Bridge. In as much as there is room for the roadway on the dam and a new bridge will soon be necessary at Farm Lane, it is only suggestive that we include the road in our design, thus eliminating an expensive bridge. An inexpensive bridge could be constructed over the spillway section. This road would not only be practical but also fit into the natural scenery around the plant.

The downstream slope should be on a 1 on $2\frac{1}{2}$ and sodded over to prevent erosion.

The existing material above the clay hardpan must be excavated and filled with a sand and gravel fill. This fill must be pakked in layers of not over 12" and rolled. This would make an impervious fill which has sufficient density,

2. Spillway Design

In the design of the spillway it is very necessary to have adequate discharge capacity. The capacity must be adequate to discharge as much water as is flowing into the reservoir. This would be the case if the reservoir was full when the disgharge is maximum.

The maximum discharge of the Red Cedar River to date is 5200 cfs occuring March 15, 1918. (Twenty five years of records). As a safety measure, the maximum was taken as 6000 cfs. Using the Francis formula- $Q = 3.33Lh^{1.5}$, a Q of 6000 cfs, L of 80 feet,-h is found to be 8.00 feet.

It is necessary then to have 8.00 feet of head on the gate which acts as a weir, for maximum flow. It is also necessary to maintain an elevation of water of 840.00 to obtain sufficient head on the wheels. With these facts in mind, we must choose a gate which will be capable of varying in elevation of 840.00 to 832.00. A floating drum gate (shown in drawing) was decided upon because it is automatic in operation.

With this spillway arrangement, much larger discharge than 6000 cfs could be obtained as there is as much as 3 feet more rise could be cared for without seriously endangering the dam. This, however, is not counted upon but would be a safety measure should the estimate of 6000cfs prove too low.

3. Plant Design

Selection of Wheels

With the values of h (head) and Q (flow) already constant, it is desireable to select a wheel to generate power. Since the head is low it is advisable to use either a propellor type or a reaction type wheel. The propellor type wheel is most used now for low heads because of high specific speed, a charactistic of that type of wheel. However, a propellor type wheel has a relatively sharp peak and a small change in gate results in a marked lowering of efficiency. To get around this disadvantage a Kaplan adjustable blade wheel could be used but due to the fact of high first cost, this wheel would be out of question.

Having a head of 15.0 feet and a Q of 300 cfs and using White's emperical formula page 227 of "Water Power Engineering" by H.K. Barrows, $N_s = \frac{632}{h^{\frac{1}{2}}}$, we get $N_s = 163$ which is rather

high for a reaction type wheel. Also assuming ϕ as 0.9 (page 212 "Water Power Engineering" by H.K. Barrows) $N = \frac{N_s h^{1.25}}{hp^{\frac{1}{2}}} =$ 238 RPM which is quite high too. $D = N_u \frac{h^{\frac{1}{2}}}{N} =$ 27 inches. $Q_u = \frac{Q}{D^2 h^{\frac{1}{2}}} = 0.106$ $P_u = \frac{hp}{D^2 h^{1.5}} = 0.0965$.

In looking in catalogues of various wheel companies we find that no wheel made has these charcteristics and therefore we cannot choose a suitable wheel. It is possible, however, to select two wheels that will give the desired power with the head and flow available.

Fron the list of wheels in Barrow's "Water Power Engineering, page 215, a representative list, a Leffel Z type wheel was chosen. That wheel has the following constants;
$N_s = 101$, $P_u = 0.00481$, $N_u = 1450$, $Q_u = 0.053$, h=15 feet , D=30 inches , Q= 185 cfs , hp=252 , N=100 R.M. This unit can be used to take care of the flow a good share of the time, (see flow-duration curve). Another wheel, an Allis Chalmers 24 inch, which has the following constants;
$N_s = 100$, $P_u = 0.00428$, $N_u = 1520$, h= 15 feet , D= 24 inches, $Q_u = 0.047$, Q= 105 cfs , hp=142 , N=100. This wheel can be used at low flow periods, and in conjunction with the first wheel during periods of high flow.

Buildings and Generators

In this preliminary investigation it is not practical to select generators and further it is out of the scope of the author's knowledge.

A suitable building must be chosen to house the power equipment. The building must be of sufficient size to accomodate two generators and have room for switchboards and other necessaries. The architecture should be such that it fits into the landscaping and architecture of the other college buildings. A suggestive design and size is shown in the drawing but no attempt was made to produce complete detailed plans.

C. Flooded Land - Area and Types of Land

The volume of water stored in the back water was found to be 6400 acre-feet or 277,740,000 cubic feet.

The area flooded behind the dam site with the water level at 840.00, is 2.76 square miles or 1766 acres. This figure was obtained from the quadrangle map with hte help of the planimeter. Of this 2.76 square miles of flooded land, 1.03 square miles is swamp land and is of little value. Of the remaining 1.73 square miles , it is estimated that only 20% or 0.35 square miles is under cultivation.

The back water would also include area containing ten houses, six of which are in the southern edge of the town of Okemos, 1.4 miles of county road,and 0.1 miles of state highway all of which would be under water. The roads could be filled as they are all less than two feet under water. Thetracks of the Grand Trunk Railroad, which passes through the flooded area, are of sufficient elevation not to be affected by the back water.

D. Cost Estimates

1. Dam, Spillway, and Power House.

These costs are the first costs.

1. Dam, Spillway, and Power House.

Excavation - 36,600 cu. yds. at 0.40	---------	$ 14,640.00
Fill Material - 3,500 cu. yds. at 1.25	--------	4,375.00
Concrete - 7,880 cu.yds. at 20.00	--------------	158,000.00
Reinforcing Steel - 113,000 lbs. at 0.05	---------	5,650.00
Steel Sheet Piling - 817,200 lbs at 0.05	--------	24,516.00
Building and Switchboard	-----------------------	8,000.00
Drum Gates 2 at 5,000.00	---------------------	10,000.00
Wheels and Generators	-------------------------	20,000.00
		$ 244,180.00

2. Flooded Land and Real Estate.

Swamp Land	- 660 acres at 50.00 --	$ 33,000.00	
Waste Land	- 886 acres at 75.00 --	66,500.00	
Farm Land	- 220 acres at 100.00 --	22,000.00	
Houses	- 10 at 3500.00 -------	35,000.00	
County Road	- 1.4 mi. at 10,000.00--	14,000.00	
State Road	- 0.1 mi. at 20,000.00--	2,000.00	
		$ 172,500.00	172,500.00
			416,680.00
Engineering and Preliminary Investigations	------		41,668.00
			458,348.00
Interest during Construction 5%	--------------		22,917.00
Contingency Fund	---------------------		25,000.00
	Total Costs ---------		$ 506,265.00

This total cost divided by the horsepower developed would give the cost per horsepower which is $ 1,617.46 per horsepower. This is very high, in fact, it is out of the question as far as economics is concerned.

Fixed and Operating costs must be figured. Insurance and depreciation amount to 9% to 10% of the cost. Operating costs amount to 0.1 cent per kilowatt-hour for attendence and operation.

E. Conclusion

Although there is a coming demand for hydro-electric power, the possibility of that type of power from the Red Cedar River is economically beyond consideration. The main factors affecting the cost are the size of the dam needed to form the pond and the amount of real estate flooded due to the flatness of the land in this vicinity. The river is not of sufficient size to expect much power because of a small drainage area and because of low available head.

This study of power development is only a preliminary type of study but it afforded the author a good opportunity to learn about hydraulic power development.

Pocket has:
3 blueprints
3 charts

THE TOPOGRAPHIC MAPS OF THE UNITED STATES

The United States Geological Survey is making a standard topographic atlas of the United States. This work has been in progress since 1882, and its results consist of published maps of more than 42 per cent of the country, exclusive of outlying possessions.

This topographic atlas is published in the form of maps on sheets measuring about 16½ by 20 inches. Under the general plan adopted the country is divided into quadrangles bounded by parallels of latitude and meridians of longitude. These quadrangles are mapped on different scales, the scale selected for each map being that which is best adapted to general use in the development of the country, and consequently, though the standard maps are of nearly uniform size, they represent areas of different sizes. On the lower margin of each map are printed graphic scales showing distances in feet, meters, and miles. In addition, the scale of the map is shown by a fraction expressing a fixed ratio between linear measurements on the map and corresponding distances on the ground. For example, the scale $\frac{1}{62,500}$ means that 1 unit on the map (such as 1 inch, 1 foot, or 1 meter) represents 62,500 similar units on the earth's surface.

Although some areas are surveyed and some maps are compiled and published on special scales for special purposes, the standard topographic surveys for the United States proper and the resulting maps have for many years been divided into three types, differentiated as follows:

1. Surveys of areas in which there are problems of great public importance—relating, for example, to mineral development, irrigation, or reclamation of swamp areas—are made with sufficient accuracy to be used in the publication of maps on a scale of $\frac{1}{31,680}$ (1 inch = one-half mile), with a contour interval of 1, 5, or 10 feet.

2. Surveys of areas in which there are problems of average public importance, such as most of the basin of the Mississippi and its tributaries, are made with sufficient accuracy to be used in the publication of maps on a scale of $\frac{1}{62,500}$ (1 inch = nearly 1 mile), with a contour interval of 10 to 25 feet.

3. Surveys of areas in which the problems are of minor public importance, such as much of the mountain or desert region of Arizona or New Mexico, are made with sufficient accuracy to be used in the publication of maps on a scale of $\frac{1}{125,000}$ (1 inch = nearly 2 miles), with a contour interval of 25 to 100 feet.

A topographic survey of Alaska has been in progress since 1898, and nearly 43 per cent of its area has now been mapped. About 10 per cent of the Territory has been covered by reconnaissance maps on a scale of $\frac{1}{625,000}$, or about 10 miles to an inch. Most of the remaining area surveyed in Alaska has been mapped on a scale of $\frac{1}{250,000}$, but about 4,000 square miles has been mapped on a scale of $\frac{1}{62,500}$ or larger.

The Hawaiian Islands, with the exception of the small islands at the western end of the group, have been surveyed, and the resulting maps are published on a scale of $\frac{1}{62,500}$.

The features shown on these maps may be arranged in three groups—(1) water, including seas, lakes, rivers, canals, swamps, and other bodies of water; (2) relief, including mountains, hills, valleys, and other features of the land surface; (3) culture (works of man), such as towns, cities, roads, railroads, and boundaries. The symbols used to represent these features are shown and explained below. Variations appear on some earlier maps, and additional features are represented on some special maps.

All the water features are represented in blue, the smaller streams and canals by single blue lines and the larger streams, the lakes, and the sea by blue water lining or blue tint. Intermittent streams—those whose beds are dry for a large part of the year—are shown by lines of blue dots and dashes.

Relief is shown by contour lines in brown, which on some maps are supplemented by shading showing the effect of light thrown from the northwest across the area represented, for the purpose of giving the appearance of relief and thus aiding in the interpretation of the contour lines. A contour line represents an imaginary line on the ground (a contour) every part of which is at the same altitude above sea level. Such a line could be drawn at any altitude, but in practice only the contours at certain regular intervals of altitude are shown. The line of the seacoast itself is a contour, the datum or zero of altitude being mean sea level. The 20-foot contour would be the shore line if the sea should rise 20 feet. Contour lines show the shape of the hills, mountains, and valleys, as well as their altitude. Successive contour lines that are far apart on the map indicate a gentle slope; lines that are close together indicate a steep slope; and lines that run together indicate a cliff.

The manner in which contour lines express altitude, form, and grade is shown in the figure below.

The sketch represents a river valley that lies between two hills. In the foreground is the sea, with a bay that is partly inclosed by a hooked sand bar. On each side of the valley is a terrace into which small streams have cut narrow gullies. The hill on the right has a rounded summit and gently sloping spurs separated by ravines. The spurs are truncated at their lower ends by a sea cliff. The hill at the left terminates abruptly at the valley in a steep scarp, from which it slopes gradually away and forms an inclined table-land that is traversed by a few shallow gullies. On the map each of these features is represented, directly beneath its position in the sketch, by contour lines.

The contour interval, or the vertical distance in feet between one contour and the next, is stated at the bottom of each map. This interval differs according to the topography of the area mapped: in a flat country it may be as small as 1 foot; in a mountainous region it may be as great as 250 feet. Certain contour lines, every fourth or fifth one, are made heavier than the others and are accompanied by figures showing altitude. The heights of many points—such as road corners, summits, surfaces of lakes, and bench marks—are also given on the map in figures, which show altitudes to the nearest foot only. More exact altitudes—those of bench marks—as well as the geodetic coordinates of triangulation stations, are published in bulletins issued by the Geological Survey.

Lettering and the works of man are shown in black. Boundaries, such as those of a State, county, city, land grant, township, or reservation, are shown by continuous or broken lines of different kinds and weights. Good motor or public roads are shown by fine double lines, poor motor or private roads by dashed double lines, trails by dashed single lines.

Each quadrangle is designated by the name of a city, town, or prominent natural feature within it, and on the margins of the map are printed the names of adjoining quadrangles of which maps have been published. Over 3,300 quadrangles in the United States have been surveyed, and maps of them similar to the one on the other side of this sheet have been published.

The topographic map is the base on which the geology and mineral resources of a quadrangle are represented, and the maps showing these features are bound together with a descriptive text to form a folio of the Geologic Atlas of the United States. More than 220 folios have been published.

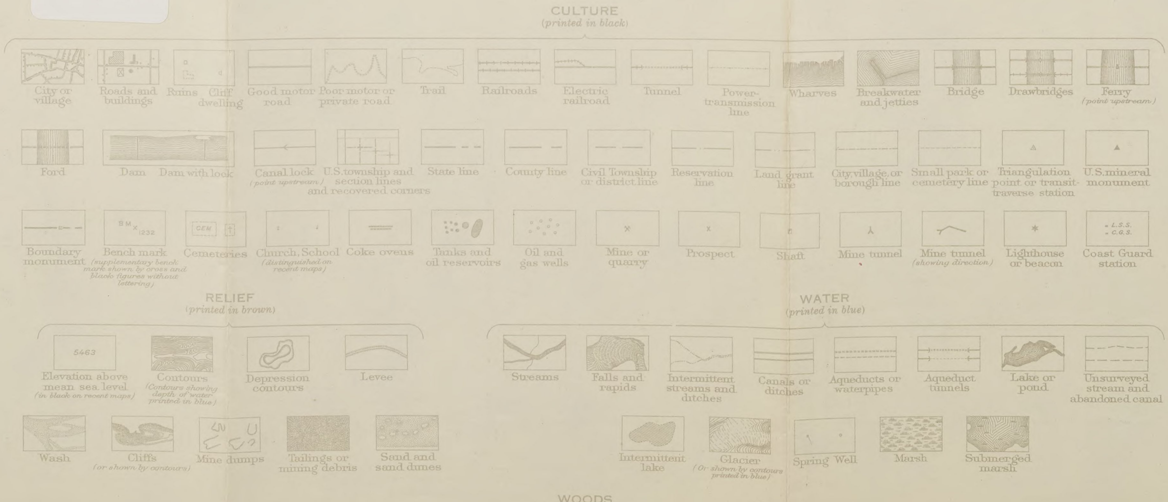
Index maps of each State and of Alaska and Hawaii showing the areas covered by topographic maps and geologic folios published by the United States Geological Survey may be obtained free. Copies of the standard topographic maps may be obtained for 10 cents each; some special maps are sold at different prices. A discount of 40 per cent is allowed on an order for maps amounting to $5 or more at the retail price. The geologic folios are sold for 25 cents or more each, the price depending on the size of the folio. A circular describing the folios will be sent on request.

Applications for maps or folios should be accompanied by cash, draft, or money order (not postage stamps) and should be addressed to

THE DIRECTOR,
United States Geological Survey,
Washington, D. C.

September, 1928.

STANDARD SYMBOLS



109
752
THS
map

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

STATE OF MICHIGAN
REPRESENTED BY THE
DEPARTMENT OF CONSERVATION
GEOLOGICAL SURVEY DIVISION

MICHIGAN
(INGHAM COUNTY)
MASON QUADRANGLE

ENGRAVED SEPT. 1911 BY U.S.G.S.

R.B.Marshall, Chief Geographer.
W.H.Herron, Geographer in charge.
Topography by C.D.S.Clarkson.
Control by C.B.Kendall and Frank H.West.
Surveyed in 1908-1909.

SURVEYED IN COOPERATION WITH THE STATE OF MICHIGAN.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1909.

Edition of Dec. 1911. reprinted 1933
Polyconic projection. North American datum

MASON, MICH.