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Geological Problems at Kerr Dam Lake County, Montana

Roger C. Rice

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GEOLOGIC PROBLEMS AT KERR DAM
LAKE COUNTY, MONTANA

by
Roger C. Rice

A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
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MONTANA SCHOOL OF MINES
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GEOLOGIC PROBLEMS AT KERR DAM
LAKE COUNTY, MONTANA

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INTRODUCTION

With an increased demand for power in Montana and surrounding territory, there is a need for existing power installations to produce more hydro-electric power. Kerr Dam, Lake County, Montana has been one of the dams selected for added output.

The existing dam and power house installation with its two hydro-electric was finished in 1938, and has been producing power ever since. The dam is an arched concrete dam, with extensive abutments on either side. Because of the nature of the country rock at the dam sits, abutments had to be carried farther away from the dam than would ordinarily be necessary. There have been no serious slides in the area, but one narrowly missed the abutments a few years ago. Cables attached to pins in the bedrock have been employed to retain large blocks over-hanging the intake gates.

A third unit is to be added to the two already installed, and in order to accomplish this, the powerhouse will have to be extended to accomodate the new unit. The powerhouse addition is to be added south of the original structure and on an area known to be crossed by a large fault, obscured by river gravel and displaced blocks from the surrounding canyon walls. A series of accurately located diamond drill holes were drilled and the resulting cores carefully studied and filed. The results of an analysis and correlation of the cores will be covered in detail in this paper.

Just west of the dam are the intake gates which control the water passing down the tunnels to the turbines. With the addition of the third unit, a new tunnel will be driven. To prevent a stoppage of power from the dam, a method of starting the tunnel without lowering the level of the pond has been devised. A shaft will be sunk behind a wall of bedrock which will be left in place. This wall will be, in effect, a natural cofferdam. In general, the problem connected with the natural cofferdam is whether or not the rock strata at the intake site will withstand the pressures subjected upon the rock by the pond behind the main dam, and whether or not the overlying strata will move when they are left unsupported.

The author has made a number of field trips to the dam to map the jointing trends of the argillite rocks of the area and to analyze the cores. Geologic sections of the important areas were made from the logs of the cores and will be included in this report.

At this time, the author wishes to thank Mr. A. B. Martin and The Montana Power Company for information and drawings used in this paper.

LOCATION

Kerr Dam, one of The Montana Power Company's chain of hydro-electric developments, lies about eight and one-half miles southwest of Polson, Montana, on the Flathead River. Polson itself is located at the southern end of Flathead Lake.

The area in which the dam lies is an "island" of pre-Cambrian Beltian age rocks, surrounded by Tertiary lake deposits. The immediate country is flat or very gently rolling and the Flathead River gorge (Photograph B, Plate I) is the only major topographic feature. The surrounding area is largely under cultivation, with wheat the most prominent crop.

The dam reservation is reached by a good gravel road from Polson, but during winter the road down into the gorge has been known to be made impassible by snow. The mean annual temperature is 45 degrees, but temperatures range from 30° below zero to 100° above. United States Highway No. 93 connects Missoula and Polson, and continues on through Polson to Kalispell and Glacier National Park.

PLATE I

Photographs near Kerr Dam, Montana

A - Photograph taken from the northeast corner of the powerhouse showing the strata dipping upstream to the east.

B - Photograph of Flathead River gorge cut into Tertiary lake deposits showing deeply eroded banks and pinnacles left under a protective cover.

A

B

PHOTOGRAPHS NEAR KERR DAM, MONTANA

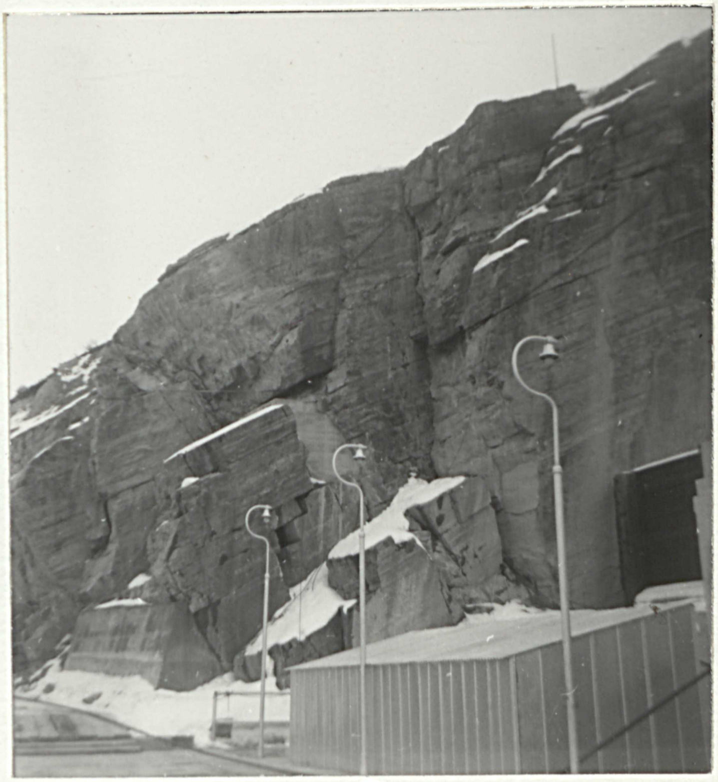
PLATE II

Photographs near Kerr Dam, Montana

A - View looking towards the powerhouse, through the "island" of pre-Cambrian strata. Lake beds show in the background.

B - View of the blocks of strata still remaining in place, formed as the result of the three directional jointing.

A



B

PHOTOGRAPHS NEAR KERR DAM, MONTANA

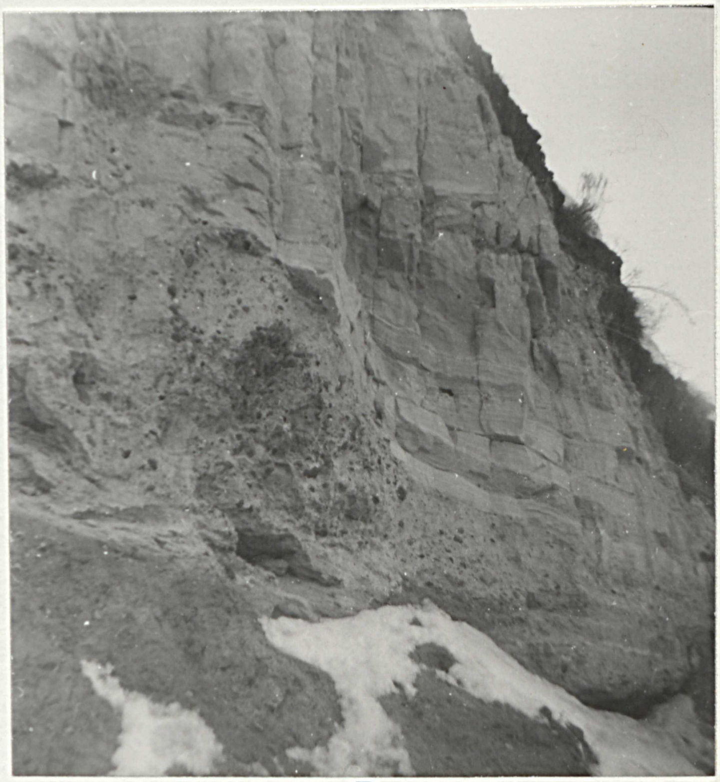
PLATE III

Photographs near Kerr Dam, Montana

A - Photograph of the dislodged blocks lying on the dip-slope below the dam.

B - Close-up of the Tertiary lake bed deposits. Photograph taken in a road cut going down to the dam.

A



B

PHOTOGRAPHS NEAR KERR DAM, MONTANA

HISTORICAL GEOLOGY OF THE GENERAL AREA

The geologic history of the Flathead valley area is typical of the mountain valley areas of northwestern Montana. There are numerous broad, flat valleys filled with Tertiary lake deposits, surrounded by high rugged mountains. The Flathead valley is quite similar to these other valleys, except in size. It is bordered on all sides by mountains. Most impressive is the Mission range on the eastern edge of the valley.

Pre-Cambrian Beltian sediments accumulated in this region to an extimated thickness of about eight miles, and this unusual mass of sediments was then covered with several thousand feet of Paleozoic and Mesozoic sediments. Toward the end of Cretaceous time there was a period of vulcanism, and it was followed by the Laramide Orogeny which formed the Rocky Mountains. At a still later time, block faults and local uplift formed barriers which backed up large bodies of water, of which Flathead Lake is a probable remnant.* Flathead Lake has grown smaller with down-cutting by its drainage rivers. The outlet, the Flathead River, has lowered its bed, and in so doing has cut a gorge deep into the Beltian rocks at the damsite, making the dam possible.

About midway between the lake and the dam is another small exposure of resistant strata. This remnant causes a restriction in the river, and may have to be removed to insure a free flow of water to the dam's reservior area.

---

*Dr. E. S. Perry, Lecture notes, September 1951

GENERAL GEOLOGY OF THE AREA

The river immediately above and below the present dam lies in a large fault zone. This fault is nearly parallel to another large fault running through the proposed powerhouse site. It has a north-south strike and, like the other faults in the area, is a strike fault. About 1000 feet below the dam, the river leaves the fault and makes a sharp bend to the west. (Plate VI) The western side of the gorge below the dam is a dip-slope and it is on this slope that large blocks may be seen. (Photograph A, Plate III) These large blocks, broken from the walls of the gorge, indicate the possibility of similar large blocks lying along the fault fissure running through the proposed powerhouse site. All faults observed in the general area are normal strike faults.

The rock forming the "island" in the Tertiary lake beds is of pre-Cambrian age, Beltian series. From the exposures and core data, the rocks were found to be mostly green to gray argillites, with thin limestone members, and very thin quartzite members. The average dip of the beds is 26^{o}N.88^{o}E., and the strike is N.2^{o}W. As is mentioned elsewhere in this paper, the joint pattern is very pronounced. Large fractures are visible that are normal to the strike (referred to on the sections as normal fractures). Some of these fractures are as much as 0.5 feet wide. Fractures parallel to the bedding are also wide-spread (referred to on the sections as bedding fractures). The third type is parallel to the strike and normal to the dip (referred to as strike fractures).

GEOLOGY OF THE POWERHOUSE SITE

With the addition of new hydro-electric unit, the powerhouse had to be extended to cover the new unit. The area to be covered with this addition was known to be over a large fault. A series of diamond drill holes were put down in the area to determine the character and depth of the bed rock. The diamond drill holes will also be used to introduce grout to the unconsolidated river alluvium. A plan view of the area showing the topography and drill hole locations may be seen on Plate VII.

The main fault, striking approximately north and south, is very nearly normal to the bedding and is dipping to the west. The fault is a normal strike fault, closely paralleling the normal north-south joint pattern of the argillite beds. There are three well-defined sets of joint planes in the area. First is the fracturing along the bedding, second is a system of joints parallel to the dip, and a third, a system parallel to the strike. A contour map (Plate VI) shows the strike fractures in many places in the area. The jointing of the rocks has a tendency to allow large blocks to fall into the river gorge and subsequently become covered with gravel. Care was taken to interpret the cores from these large blocks, because there was a danger of falsely calling them bedrock. (Photograph A, Plate III, showing similar blocks lying on the slope)

As the cores were analyzed and interpreted, there was an occurrence of seams or crevices containing loose washed river gravel. When more cores were analyzed and sections drawn, the gravel seams began to assume a definite pattern.

The gravel seams, when plotted on a section, followed the exact bedding angle for each particular section. On the front line of drill holes, seven and possibly eight gravel seams were encountered. (Plate VIII) The fault fissure, traced definitely to elevation 2640, narrowed considerably with depth. At some of the gravel seams, thin plates of quartzite were observed. By calculating the approximate location of an outcrop of one of these seams from the angle of dip of the strata and the depth of the seam according to the drill hole data, an outcrop was found. This outcropping bed was the same as the one found at about elevation 2640, and was within approximately seven feet of the calculated outcrop. The corresponding exposed bed had voids up to 5" thick and extending into the bedrock for six or more feet. Around the openings to these voids, there were plates of quartzite approximately 1/4 of an inch thick and 1/2 of a square foot in area. These voids, being above the present water level did not have a gravel filling, but it may be assumed that under conditions similar to those encountered in the holes, they would be filled with river gravel.

FORMATION OF GRAVEL SEAMS: The action necessary in starting the gravel seams was undoubtedly the result of the fault movement. The rock in the area is largely argillite with thin members of brittle quartzite. The movement of the fault,

PLATE IV

Photographs near Kerr Dam, Montana

A - View down the gorge formed by the Flathead River along a large north-south fault. The trace of the fault may be seen at the point where the gorge makes a sharp bend to the left.

B - Kerr Dam from the downstream side showing a small overflow.

A

B

PHOTOGRAPHS NEAR KERR DAM, MONTANA

PLATE V

Photographs near Kerr Dam, Montana

A - View across the river from the powerhouse. The trace of the fault is covered by the heavier snow.

B - Fault exposure on the south side of the river. The camera was held nearly vertical to make this photograph.

A

B

PHOTOGRAPHS NEAR KERR DAM, MONTANA

while slightly bending the more resilient argillite, would fracture the thinly-bedded brittle quartzite. The fault itself, having the upthrown side also the upstream side, would have formed a waterfall. The bedding, dipping upstream, would allow the force of the water to expend itself against the already fractured quartzite. The fractured quartzite member would be flushed down and out, leaving a void. As conditions changed, the river bed, and therefore the fault fissure, would fill with gravel and likewise fill the voids with rounded river gravel. Larger pebbles and cobbles, jammed in the openings would prevent slumping of overlying beds.

<u>CONSOLIDATION OF THE RIVER FILL</u>: Since the powerhouse will be constructed over the fill in the fault fissure, the fill had to be consolidated to such an extent that it would support the new structure. The drill holes in the area served as channels for the introduction of a grout mixture. The grout, a mixture of cement, fine sand, alfesil, and water, was forced into the holes under pressure. The resultant, a mixture of grout, gravel, and rock, forms a strong base for further construction. Further drilling and grouting continued until the grout stage was within a short distance of the top of the fill. A cofferdam will be constructed to hold back the river water while the foundations for the powerhouse addition are being excavated in the consolidated fill. The excavation will also serve as a check on the success of the grouting measures.

GEOLOGY OF THE INTAKE AREA

The new intake tunnel will run parallel to the other two tunnels now in operation (Plate VI) and just south of them. A method of starting the tunnel at the intake end without effectively lowering the pond level has been devised, and the general idea is outlined below.

Rather than lower the pond level during construction, a natural cofferdam, made by leaving a dam of the bedrock in place, will be tried. A vertical excavation or shaft will be made in the rock, then the horizontal tunnel will be driven from the bottom of this vertical excavation. The main problem is whether the inclined strata (Plate XII) will support the pressure of the pond, and also, whether the overlying strata will slide into the vertical excavation. With the strata dipping into the excavation, the beds above the excavation may not be competent enough to resist the gravitational forces acting upon them. Once the tunnel was started, and the portal and abutments installed, the beds would have something to rest against.

If the overlying beds show a tendency to slide, and it is entirely possible that they may, the author suggests a series of rock bolts, similar to those now being used to replace, under certain conditions, timbering in some mines. These rock bolts could either be anchored into a competent bed that lies below the bottom limits of the vertical excavation (Plate XII), or they could be used to tie a number of beds together and gain strength in that way. Since there may be two tunnels driven, there would be ample space between the two tunnels to drive the anchor bolts below the bed at the bottom of the excavation. During blasting, these bolts would further strengthen the strata in case there was a further inclination of the beds to slide.

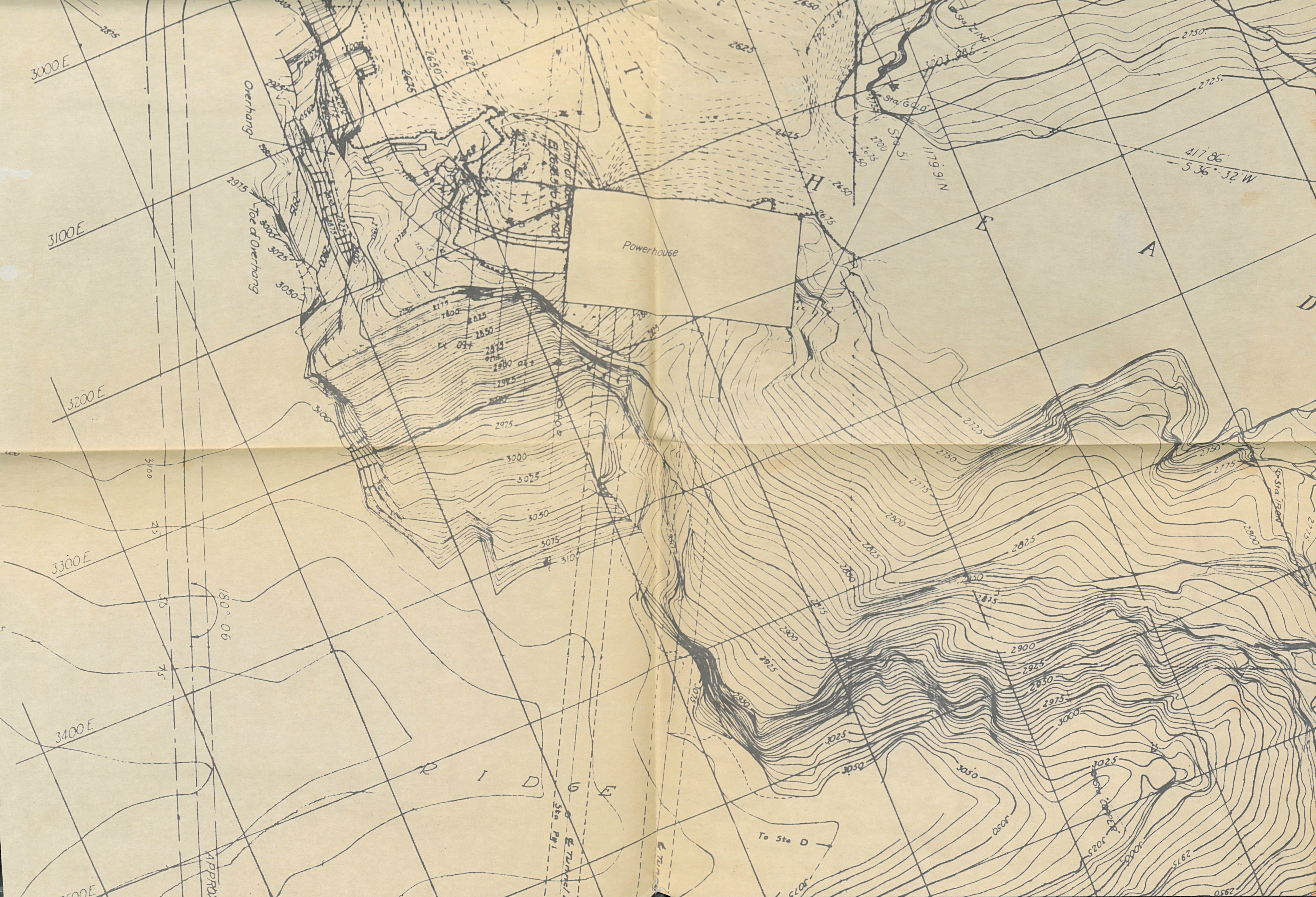
On the other side of the vertical excavation (the pond side) there would be very little, if any, tendency for the strata to move. Once the fractures were sealed, the natural dam would be water-tight, and since the strata are inclined towards the pond, the resultant of the forces set up by the pressure head of the pond would further immobilize the beds. There is fill up to within 15 feet of the present water surface. This fill will also help prevent movement of the beds.

CONCLUSION

In conclusion, the author wishes to say that all the information, both in the text and cross-sections, represents the author's ideas on the formation of the long gravel seams encountered in the bedrock below the proposed powerhouse site.

The problem of consolidating the fill at the powerhouse site will be solved by sufficient grouting. At the intake area, little trouble should be encountered with leakage, once the fractures are sealed. It is not likely that the strata will fail on the pond side of the vertical excavation. The inclined strata above the excavation may have a tendency to move, but the proper application of rock bolts will probably prevent movement.

PLATE VI


3000 E
3100 E
3200 E
3300 E
3400 E
3500 E
Overhang
Toe of Overhang
Powerhouse
T
H
E
A
D
R I D G E
APPRO
Sta ZINC
Sta GOLD
Sta 51
1179.91 N
1203.98 E
417.86'
S 36° 32' W
Sta IRON
Sta COPPER
To Sta D
Sta PM 1
℄ Tunnel
180° 06'
2625
2650
2675
2700
2725
2750
2775
2800
2825
2850
2875
2900
2925
2950
2975
3000
3025
3050
3075
3100

3400 E
3500 E
3600 E
3700 E
3800 E
RIDGE
APPROXIMATE ℄ OF NEW W.L. TUNNEL 1
Sta Pt 1
℄ Tunnel Main
℄ Tunnel 3
To Sta D
Power Line
Road Switch back
Down
℄ Penstock No. 1
℄ Penstock No. 2
INTAKE
Sta
Sta
A
90° 00'
2900
2925
2950
2975
3000
3025
3050
3075
2900
2925
2950
2975
3000
3025
3050
3025
3000
2975
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2850
2825
2775
2750
3075

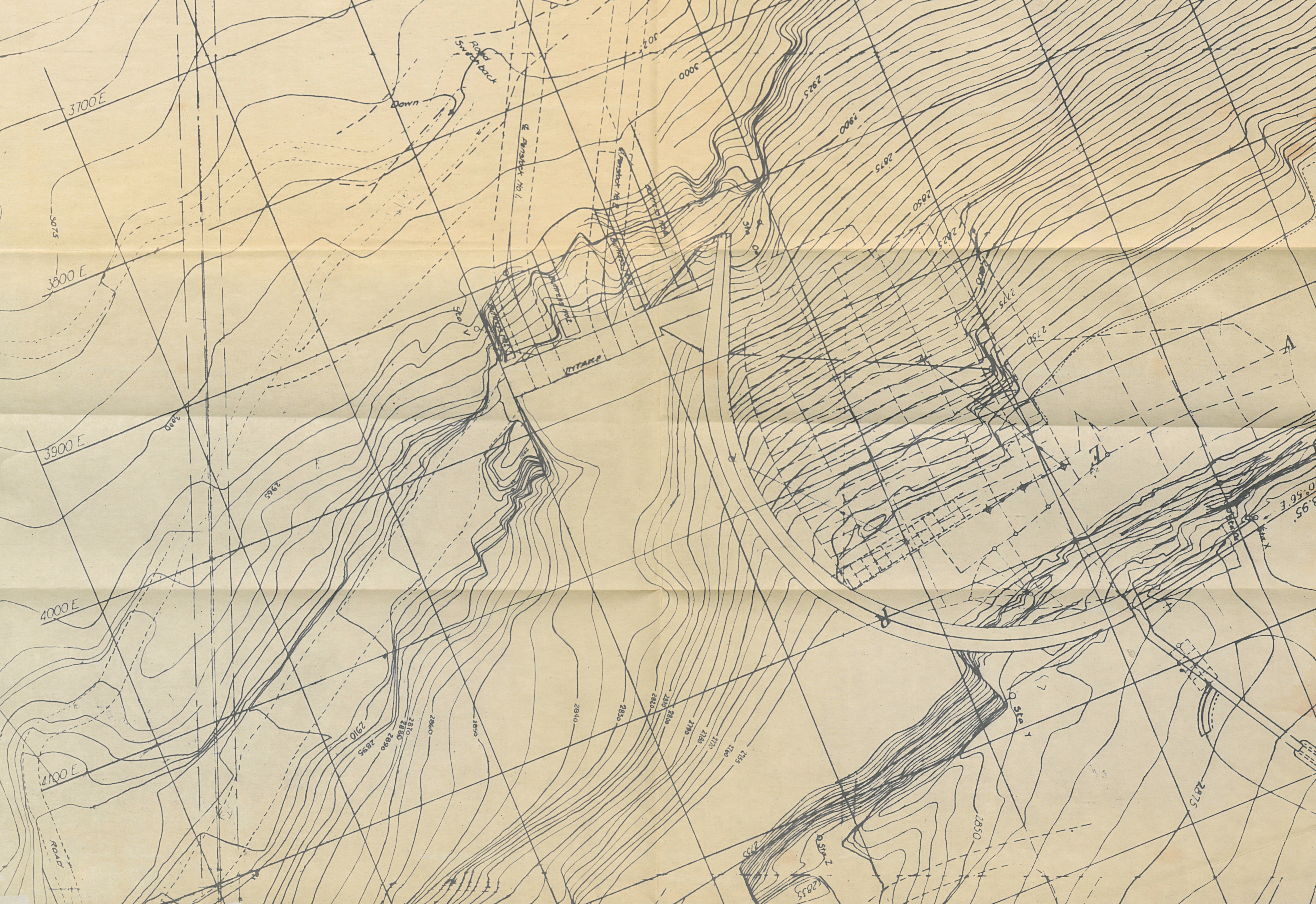
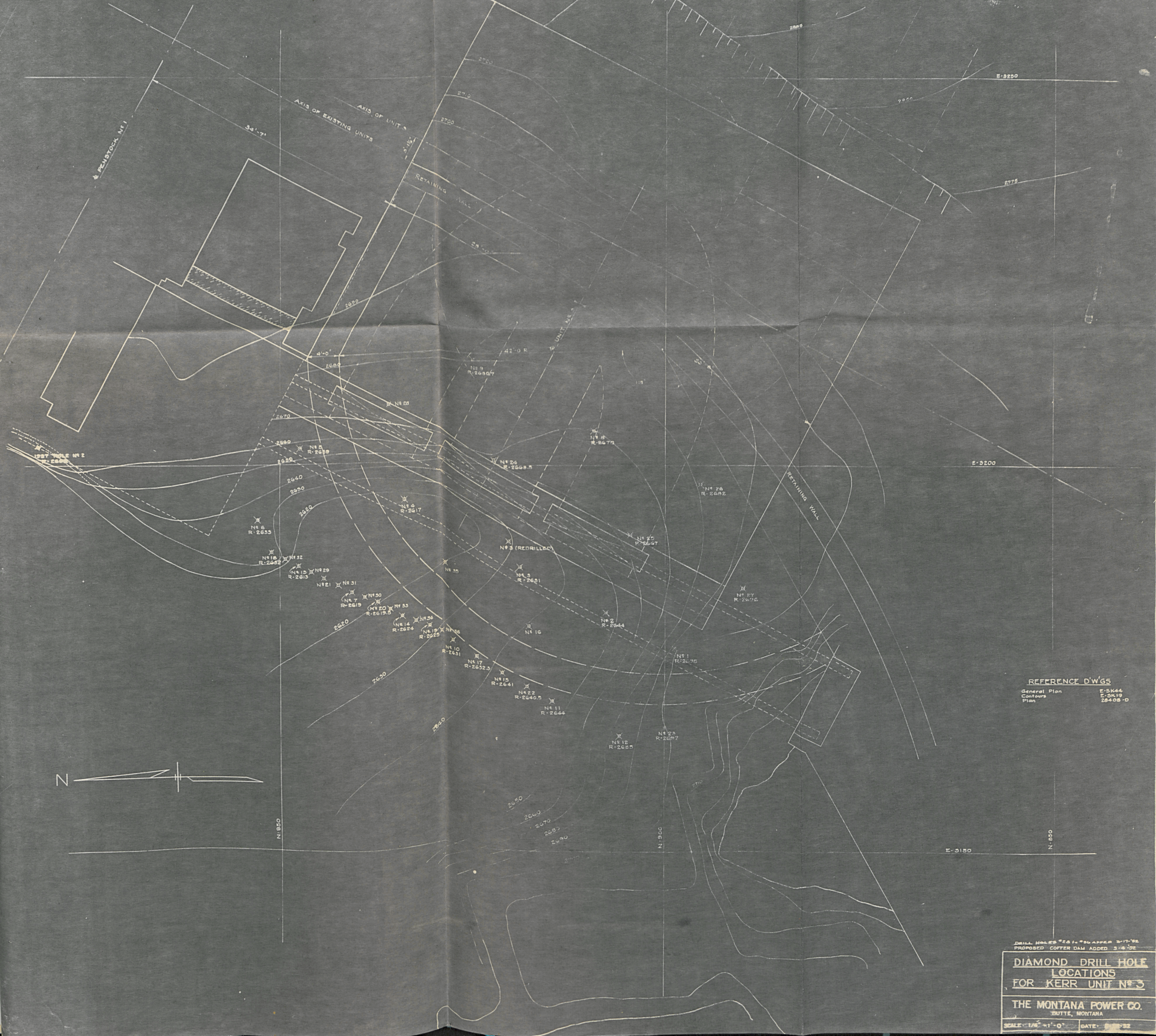

Road Switchback
Down
3700 E
3800 E
3900 E
4000 E
4100 E
3075
3000
2925
2900
2875
2850
2825
2775
2750
℄ Penstock No. 1
℄ Penstock No. 2
Buttress No. 1
Buttress No. 2
Buttress No. 3
Buttress No. 4
Sta V
Sta W
Intake
A
Z
R
Sta X
Sta Y
Sta Z
3.95'
0°56' E
3900
2965
2910
2895
2890
2880
2870
2860
2850
2840
2830
2820
2800
2790
2780
2770
2760
2755
2875
2850
2755
2835
Road

PLATE VII



REFERENCE D'W'GS

General Plan	E-SK44
Contours	E-SK19
Plan	28408-D

DRILL HOLES #28 to #36 ADDED 3-17-'32
PROPOSED COFFER DAM ADDED 3-4-'32

DIAMOND DRILL HOLE LOCATIONS FOR KERR UNIT Nº 3

THE MONTANA POWER CO.
BUTTE, MONTANA

SCALE: 1/8" = 1'-0"
DATE: [illegible]-32

PLATE VIII

DRILL HOLE DATA

Hole No.	Coordinates N.	Coordinates E.	Collar	Bedrock	Bottom
6	957.8	3183.0	2654.0	2633.0	2603.0
7	940.[illegible]	3183.[illegible]	2655.0	2619.0	2603.5
10	927.4	3176.[illegible]	2667.0	263[illegible].0	2631.0
11	914.8	3169.5	2663.0	2644.0	2644.0
12	905.8	3165.0	2685.0	2685.0	2636.0
13	94[illegible]	3167.0	2653.0	2619.0	2602.0
14	934.8	3160.0	2650.5	2624.0	2592.0
15	920.8	3175.0	2661.0	2633.0	2619.0
17	927.2	3174.8	2660.0	2632.3	2616.0
18	95[illegible].0	3188.8	2670.0 (rim)	263[illegible].0	2606.0
19	930.[illegible]	3176.4	2672.0 (rim)	2625.0	2595.0
20	93[illegible]	318[illegible].0	2672.0 (rim)	2619.5	2606.0
21	94[illegible]	3185.[illegible]	2672.0 (rim)	?	2598.0
22	91[illegible]	317[illegible]	2674.0 (rim)	2640.[illegible]	2598.0 (?)

Bearing of Section — S. 28°48' W. (approx.)

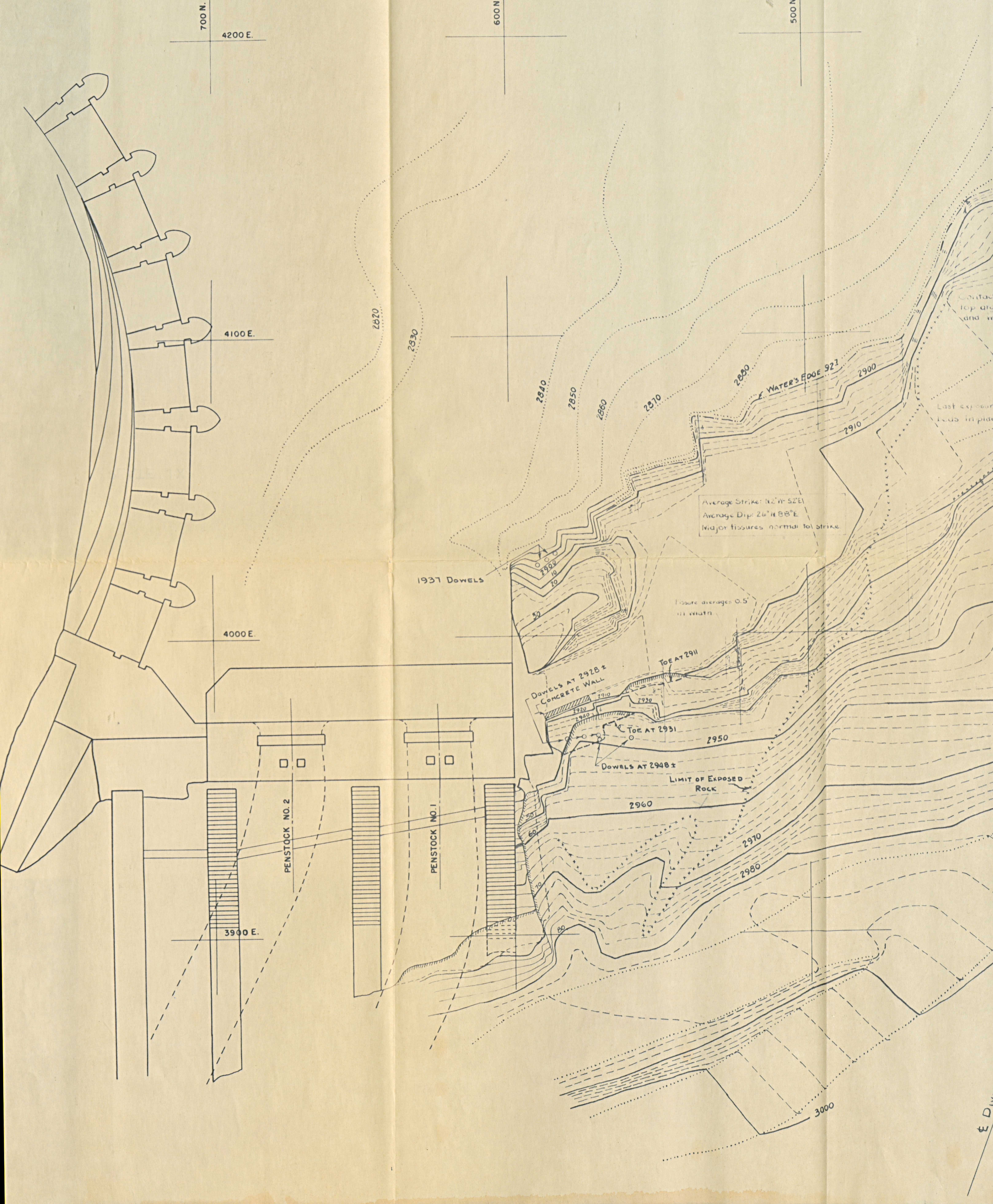
Apparent Dip — 12°30"

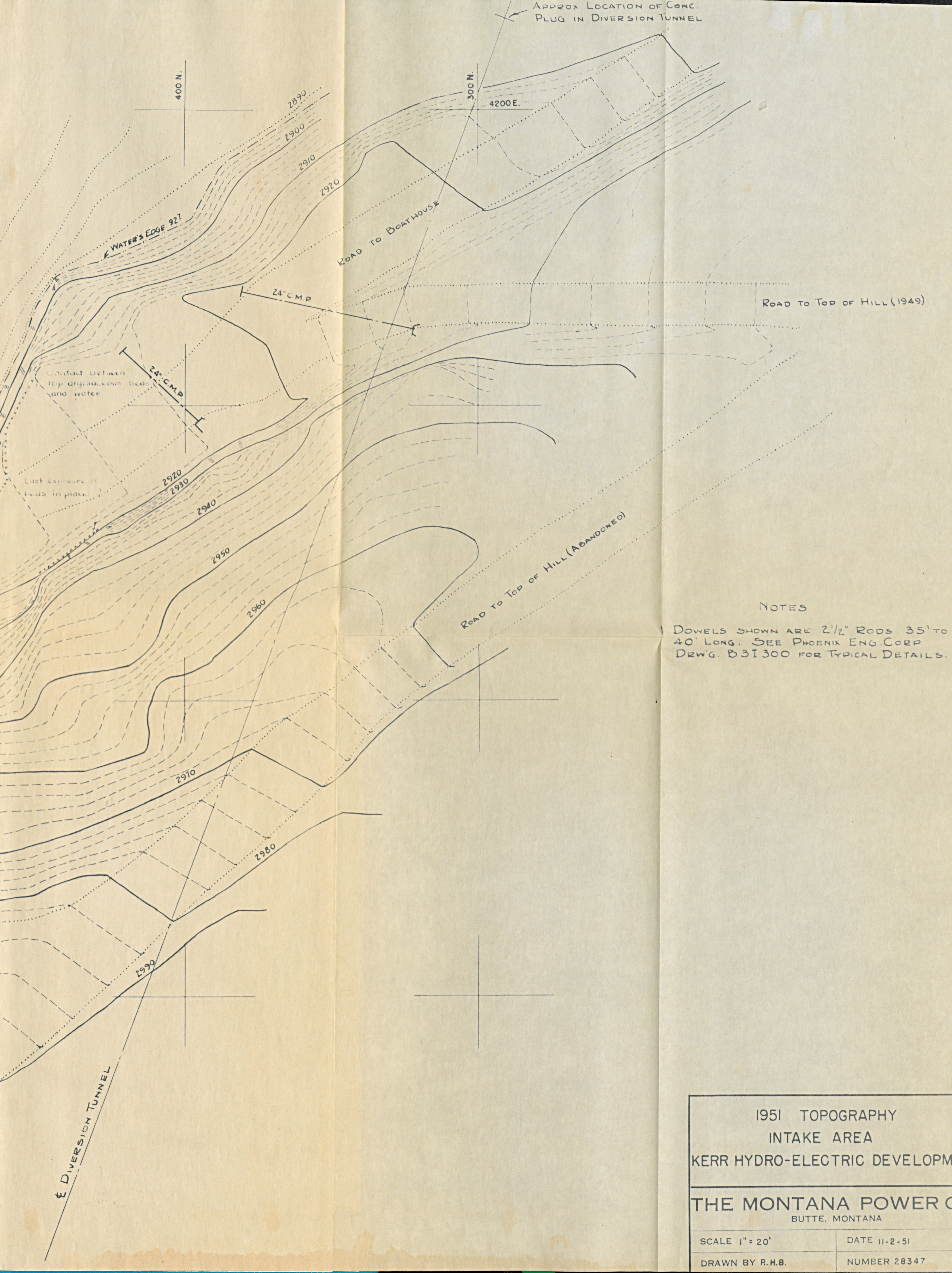
True Dip - 26° N. 88° E., Strike - N. 2° W.

KERR No.3 UNIT
FOUNDATION DRILLING
Section through holes
6,7,10,11,12,13,14,15,17,18,19,20,21,22

THE MONTANA POWER CO.
BUTTE, MONTANA

PLATE IX


700 N.
4200 E.
600 N.
500 N.
4100 E.
4000 E.
3900 E.
2820
2830
2840
2850
2860
2870
2880
WATER'S EDGE 927
2900
2910
2920
2930
2940
2950
2960
2970
2980
3000
10
20
50
60
80
Average Strike: N.2°W-S2°E
Average Dip: 26° N.88°E
Major fissures normal to strike
Fissure averages 0.5' in width
1937 DOWELS
DOWELS AT 2928 ± CONCRETE WALL
TOE AT 2911
TOE AT 2931
DOWELS AT 2948 ±
LIMIT OF EXPOSED ROCK
PENSTOCK NO. 2
PENSTOCK NO. 1



NOTES

1 Dowels shown are 2½" Rods 35' to 40' Long. See Phoenix Eng. Corp. Drw'g. B31300 for Typical Details.

1951 TOPOGRAPHY
INTAKE AREA
KERR HYDRO-ELECTRIC DEVELOPMENT

THE MONTANA POWER CO.
BUTTE, MONTANA

SCALE 1" = 20'	DATE 11-2-51
DRAWN BY R.H.B.	NUMBER 28347 C

PLATE X

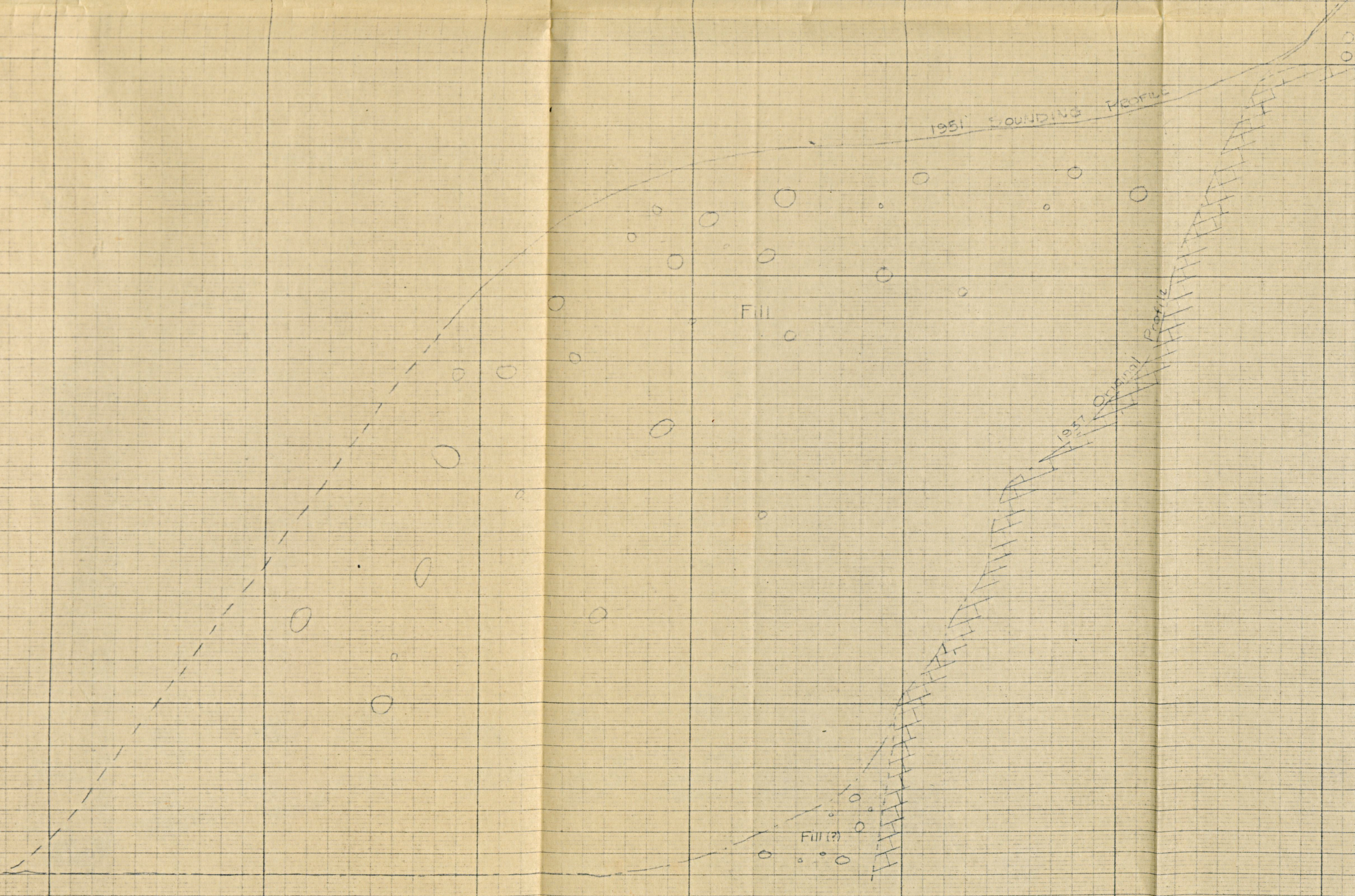
ISOMETRIC VIEW OF SECTION X-X
SHOWING TYPICAL FRACTURE PLANES

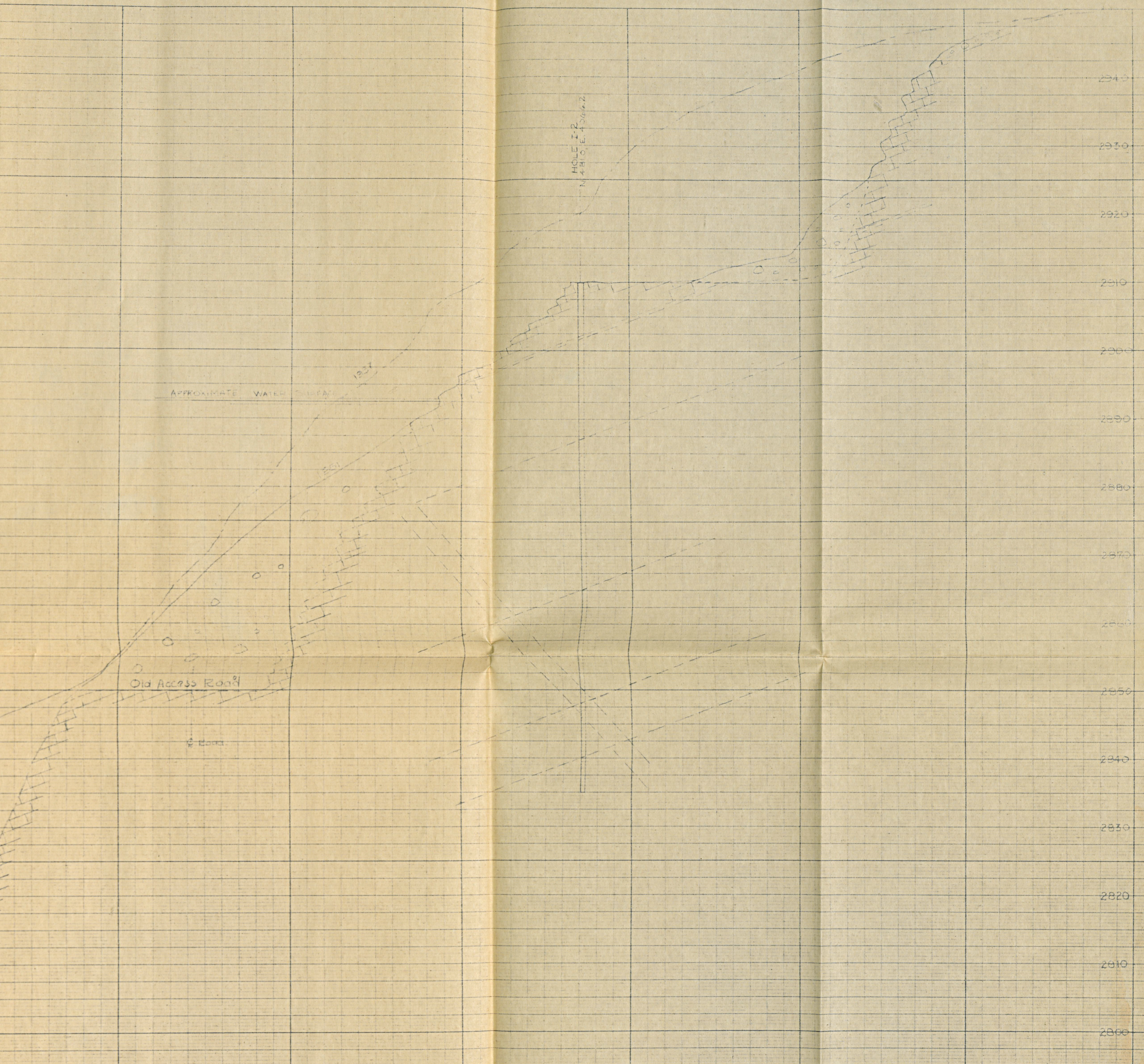
HOLE	COORDINATES		COLLAR	BEDROCK	BOTTOM
	N	E			
I-2	481.0	4066.2	2910.0	2910.0	2835.0

Bearing of Section B ~ N 51°10'E
Apparent Dip ~ 20°45'
True Dip ~ 26° N 88E, Strike ~ N. 2°W.

KERR No. 3 UNIT
INTAKE DRILLING
SECTION B THROUGH HOLE I-2
THE MONTANA POWER CO.

PLATE XI


1951 Sounding Profile
Fill
1937 Original Profile
Fill (?)



Bearing of Section: N 51° 10' E.
Apparent Dip: 20° 45' (This Section)
True Dip: 26° N 88° E, Strike: N 2° W.

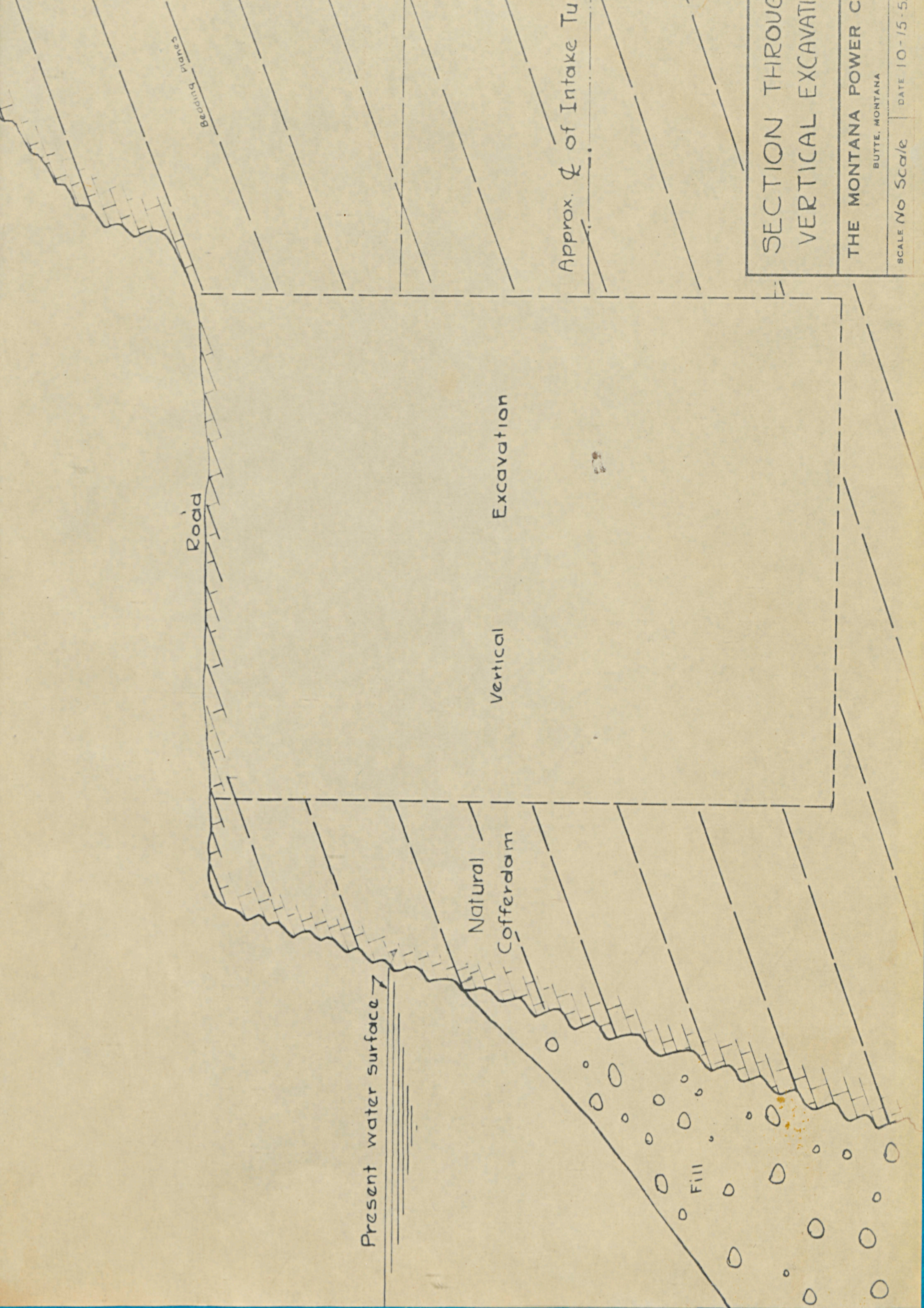
KERR Nº3 UNIT
Section Through Hole I-2
INTAKE AREA

THE MONTANA POWER CO.
BUTTE, MONTANA

SCALE: 1"=10'-0" DATE: 3-21-52

DRAWN BY: Rice NUMBER:

PLATE XII



SECTION THROUGH
VERTICAL EXCAVATIO

THE MONTANA POWER CO.
BUTTE, MONTANA

SCALE No Scale
DATE 10-15-52