UNITED STATES

DEPARTMENT OF THE INTERIOR

Geological Survey
W. C. Mendenhall, Director

Conservation Branch
Herman Stabler, Chief

Estimate of Depth to Bed Rock at Some Dam Sites in the Gunnison, Little Colorado and Zuni River Basins, Colorado and Arizona Based on Resistivity Measurements 1938-1939

By

H. Cecil Spicer

November 1940

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Estimates of Depth to Bed Rock at some dam sites in the Gunnison, Little Colorado, and Zuni River basins.

1938-39

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H. Cecil Spicer

In order to obtain estimates of the thickness of the deposits overlying the bed rock at the dam sites given in the report by Piper [1/], an investigation was undertaken, Benjamin E. Jones supervising. The earth resistivity method in conjunction with the Gish-Rooney apparatus was used in the determinations of depths of fill at all of the dam sites of this report.

The dam sites that are reported herein were located on the Lake Fork Gunnison, main Gunnison and East Rivers in Colorado; and on the Zuni and Little Colorado Rivers in Arizona.

The field personnel were: H. Cecil Spicer, party chief; assisted by John Pesheck, recorder; Arthur B. Wells, Byron S. Flynt Chester W. Thurston, Jr., F. W. Dyer, Jr., rodman; the party maximum was never over four members.

In general, the work was performed during very favorable weather conditions. The field work was begun August 2 and completed

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1/ Arthur M. Piper, Geologic features of certain dam sites in the Bear River, Colorado, River, and Rio Grande basins, 1936-37.

November 2, 1938. The interpretation of results and the preparation of the report was done by Mr. Spicer during the period November 16, 1938 to January 25, 1939.

The original resistivity curves are not submitted as a part of the report; but have been interpreted and the results presented in figures and tables where possible, along with some comments. The Lee modification of the Wenner configuration of electrodes was used throughout the observations, consequently, all intervals indicate the total distance between the potential electrodes and should in every instance be divided by 2 in order to obtain the distance from the center of the line or station; i. e. the half interval indicates the distance from the line center or station. P_1 is always run upstream or uphill, and P_2 in the opposite direction and thus indicate the portions of the apparent resistivity above and below the center of the line.

Figures 1A and 19A, that explain the geology on the maps of the sites on the Lake Fork Gunnison, Gunnison and East Rivers, are included for convenience, and the coloring scheme is the same as used by Piper in his report on the geologic features.

Gunnison River

East River Dam Site (#4-C)

Four of the seven resistivity lines completed at this site were to determine the thickness of the overburden, while the other three were to estimate the thickness of the high terrace deposit and the Dakota (?) sandstone. Formation tests were made on the different materials at the site in order to assist in the interpretation of the resistivity curves.

Figure 1 shows the location of the resistivity lines with respect to the proposed axis, direction of the line of electrodes, and the maximum interval for each. The summary of the interpretations of the resistivity curves is in Table 1. A cross section along the axis, Figure 2, was drawn with the aid of Figure 1 and Table 1, and shows the probable granite bed rock surface. Layering as indicated from the curves is shown for each station in Figure 3.

The topography was such that a long line was not feasible on the 8,170 contour at the axis, so line 4 was located 47.5 feet above and about the middle of an outcrop of sandstone upstream from the axis on the right abutment. The up- and downstream extent of the sandstone outcrop appeared to be small, and the resistivity curve for the line indicates that the sandstone rapidly thins out upstream from the center, but downstream the thinning is slower and is probably nearly discontinuous in both directions

within the 150-foot interval. Continuous granitic rock is covered to about 129 feet, somewhat deeper than the map indicates at this point.

Line 6 was limited in extent by the topography, but the curve indicates the thickness of the sandstone, also, that the granite is horizontally discontinuous in both directions of the line and the overburden thickness correspondingly.

Considerable difficulty was encountered on the right abutment in trying to locate the centers of the resistivity lines and their directions so that they agreed with the topography and the geology. Probably both are of sketch quality.

Formation tests on the granite rock of the left abutment gave a range of 147,850 to 465,000 ohm cm. A damp layer of decomposed granite and soil covered the harder rock, and is thought to be the cause of the low values obtained at the smaller intervals. A formation test on the dry (Dakota?) sandstone gave a range of 39,060 to 54,375 ohm cm. over the same intervals.

Results interpreted from the apparent resistivity curves of Lines 4, 5, 6, seem to not be in agreement with the geological interpretations for the right abutment. Line 4 shows that granite rock lies below the discontinuous sandstone; Line 6 indicates a granitic layer below the sandstone that is deepening in both directions of the line; and Line 5 has a bedrock layer with an apparent resistivity so high that it would be rather difficult to interpret it other than granitic. Thus it appears that the granitic rock is con-

tinuous in the right abutment, and the sandstone layer is discontinuous somewhere between Lines 4, 6, and 5.

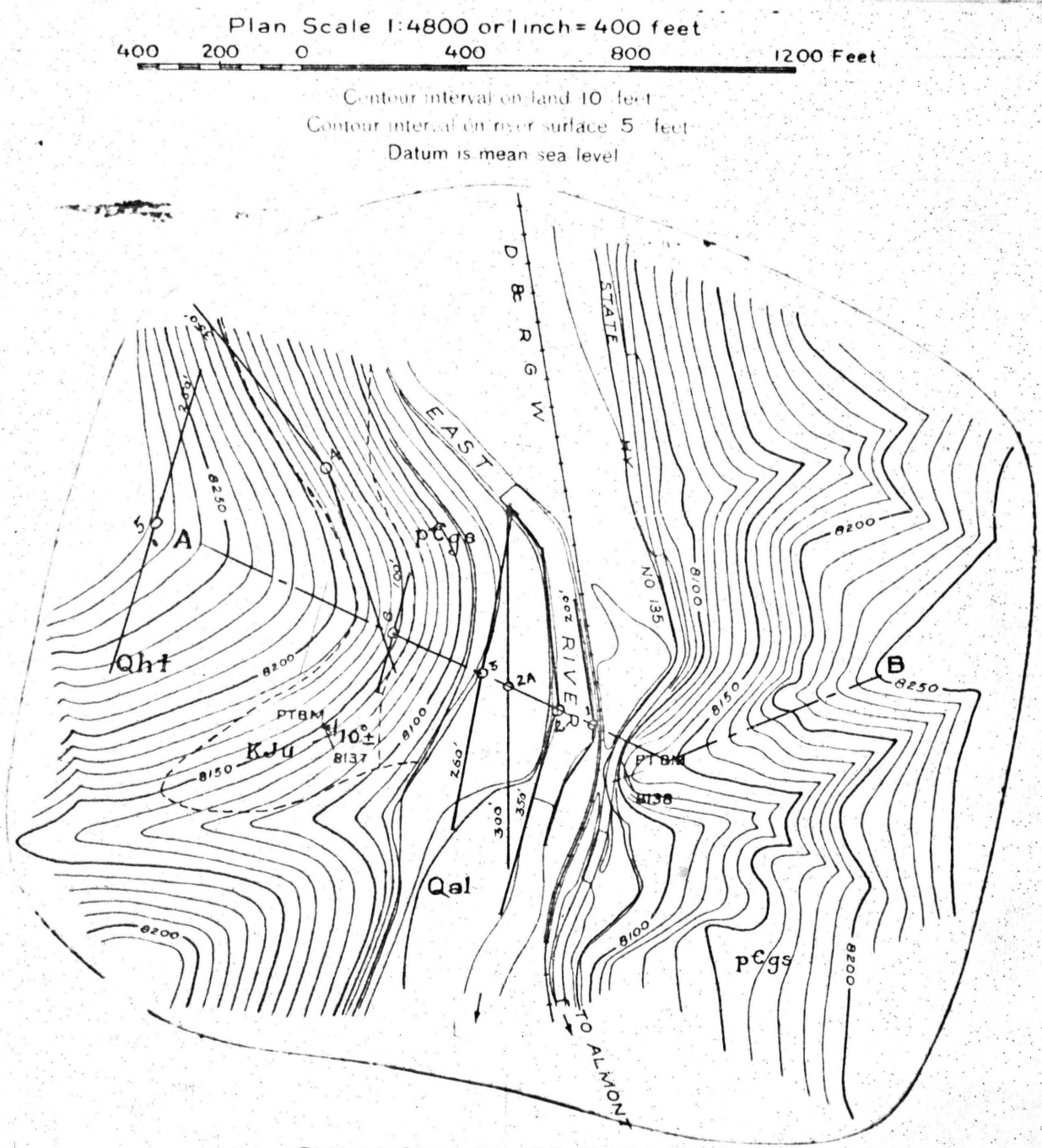


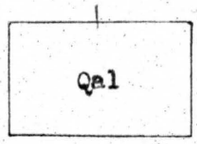
Figure 1

Location, direction, extent and maximum interval of resistivity lines,

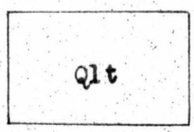
East River Dam Site

EXPLANATION

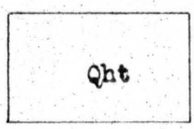
FOR GEOLOGIC MAPS OF DAM SITES ALONG THE GUNNISON RIVER, COLORADO.



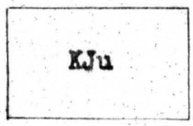
FLOOD-PLAIN DEPOSIT
(coarse gravel and boulders)



LOW-TERRACE DEPOSIT
(gravel and cobbles with some sand and boulders)

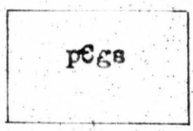


HIGH-TERRACE DEPOSIT
(unsorted sand, gravel, and large subangular boulders)



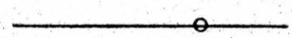
DAKOTA SANDSTONE, MORRISON FORMATION,
AND SOME OLDER SEDIMENTARY ROCKS;
NOT DIFFERENTIATED
(largely medium-grained sandstone, in part earthy, commonly cross-bedded; somewhat friable if weathered)

UNCONFORMITY

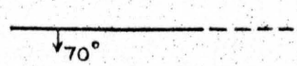


GRANITE, SCHIST, AND RELATED ROCKS
(biotite granite or quartz-monzonite enclosing extensive plates of schist, the whole cut by younger granite; also, dense massive schist intimately invaded by granitoid stringers. Ruled color pattern indicated areas in which these rocks are concealed by talus and slope wash)

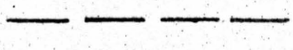
STRIKE AND DIP OF SCHISTOSITY



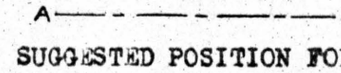
VERTICAL FRACTURE



STRIKE AND DIP OF INCLINED FRACTURE



ZONE OF DISCONTINUITY BETWEEN SETS OF FRACTURES



SUGGESTED POSITION FOR DAM

Table 1

Summary of interpretations of apparent resistivity curves

East River (Gunnison 4C) Dam Site

Line or Station	Location	Elevation feet	Maximum Electrode Interval feet	Estimated ± 10 % Depth of fill feet	Estimated ± 10 % Thickness of bedrock feet
1.	Left bank, water's edge, on axis	8045	200	43	< 150
2.	Right bank, water's edge, on axis	8045	350	75	> 275
2A.	Right bank, on axis, on Qal, 139 feet from line 2	8065	300	63	> 225
3.	Right bank, on axis, on Qal. 219.2 feet from line 2 on right abutment	8070	260	4	> 225
4.	See Fig. 1, on right abutment	8170	350	129*	> 200
5.	See Fig. 1, on right abutment	8280	250	54*	> 200
6.	250 feet above Line 3, on right abutment	8150	100	16*	> 75

* Depth to granite.

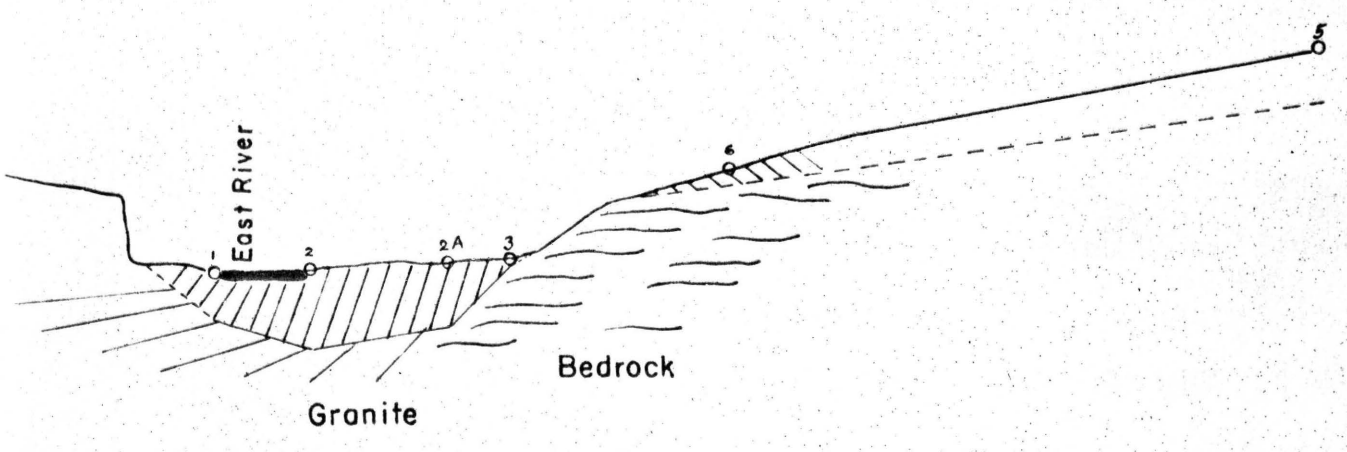


Figure 2

Cross section along axis with bed rock profile

East River Gunnison R#4c Dam Site

1"= 200'

Layers beneath resistivity line centers

East River (Gunnison R. 4C) Dam Site

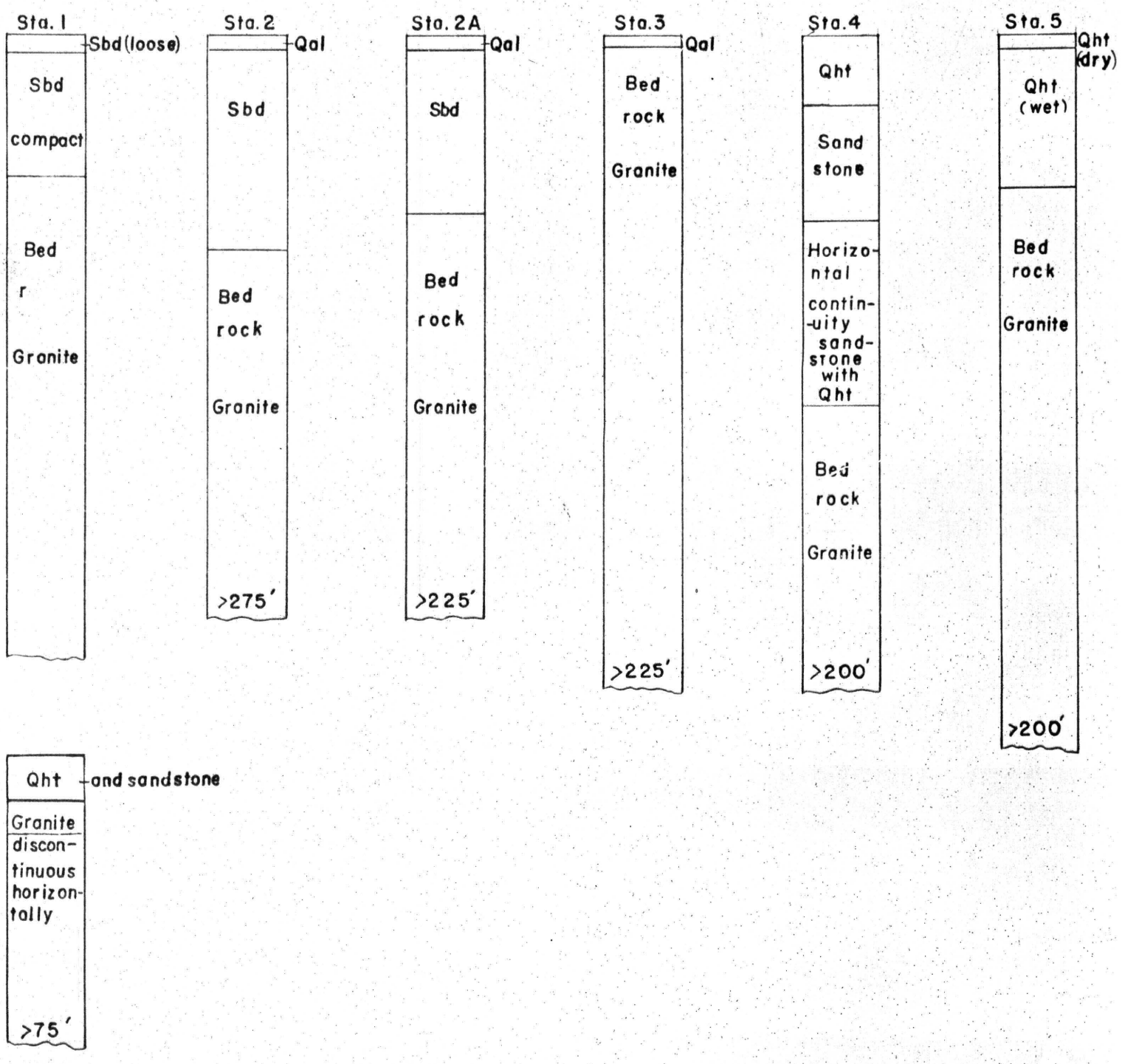


Figure 3

1" = 50'

Gunnison River

Almont Dam Site (# 3)

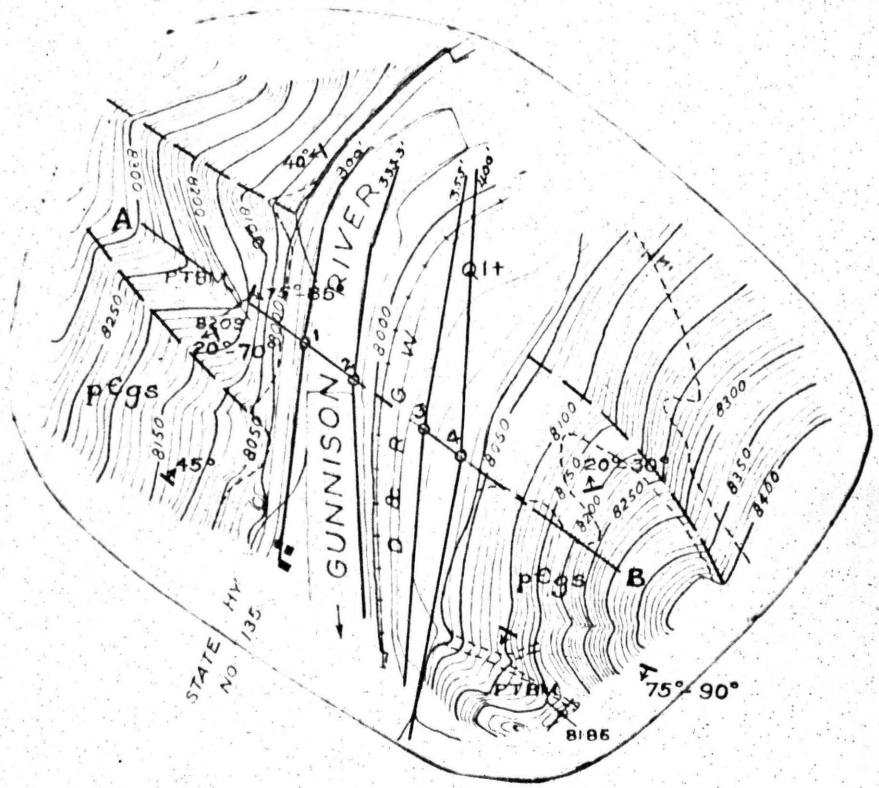
Four resistivity lines were completed at this site in order to determine the thickness of the low-terrace deposit. Figure 4 shows the location of the lines with respect to the proposed axis, direction, and the maximum interval for each.

The results from the interpretation of the apparent resistivity curves are given in Table 2. A cross section along the dam axis with the depths to bed rock is shown in Figure 5 and was prepared from Figure 4 and Table 2. The probable layering is estimated in Figure 6 for each of the stations.

Lines 1 and 2 indicate that the bed rock surface is about the same depth in both directions from the center station. Lines 3 and 4, however, trend toward the interpretation that more continuous bed rock lies upstream and the thickness of the overburden above it probably decreases in the upstream direction; while downstream from the center, horizontal discontinuities appear to be present on the two curves that would increase the depth to continuous bed rock. The intervals from 200 to 400 feet on line 4 were taken following a heavy rain, and may be slightly different from the ones that would have been obtained if the traverse could have been completed before the ground was soaked. A line higher up the slope from station 4 would have been desirable, but the nature of the terrain made it im-

practical to obtain as so many large boulders were present.

It was not possible, topographically, to extend line 1 to an interval large enough to see if there was any change in the character of the apparent resistivity curve as it passed from the massive granite to the inclosing massive schist.



GUNNISON RIVER DAM SITE NO. 3
MILE 39 Almont

Figure 4

Location, direction, extent and maximum interval of resistivity lines, Almont Dam Site.

Table 2

Summary of interpretations of apparent resistivity curves

Almont (Gunnison River # 3) Dam Site

Line or Station	Location	Elevation feet	Maximum Electrode Interval feet	Estimated ±10 % Depth of fill feet	Estimated ±10 % Thickness of bedrock feet
1.	Right bank, edge of road, on axis, 10 feet from stream	7993	300	33	> 270
2.	Left bank, water's edge, on axis	7981	333 1/3	100	> 230
3.	165 feet along axis from line 2, left bank	8023	355	120	> 200
4.	100 feet along axis from line 3, left bank	8035	400	122	> 100

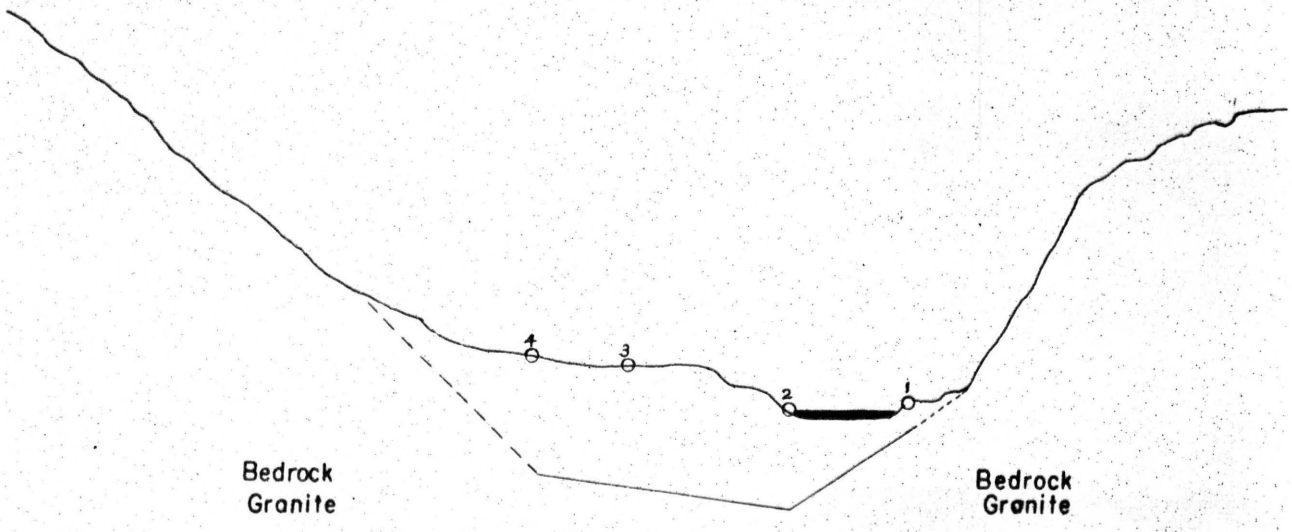


Figure 5

Cross section along axis with bedrock profile

Altmont (Gunnison R. #3) Dam Site

1" = 200'

Layers beneath centers of resistivity lines

Almont Gunnison R#3 Dam Site

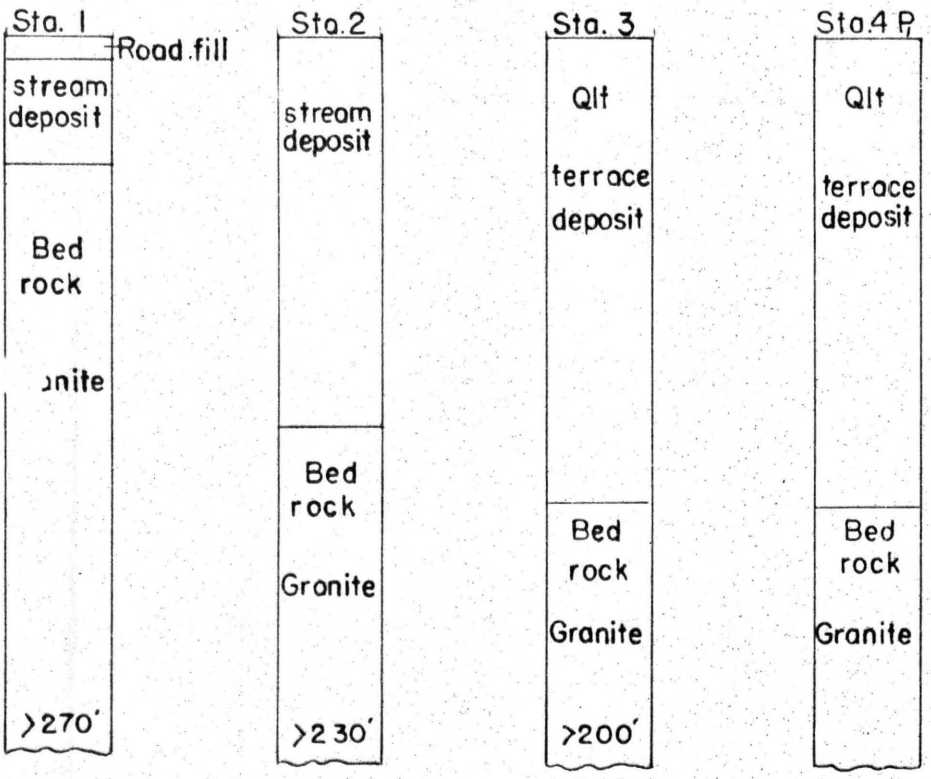


Figure 6

1" = 50'

Gunnison River

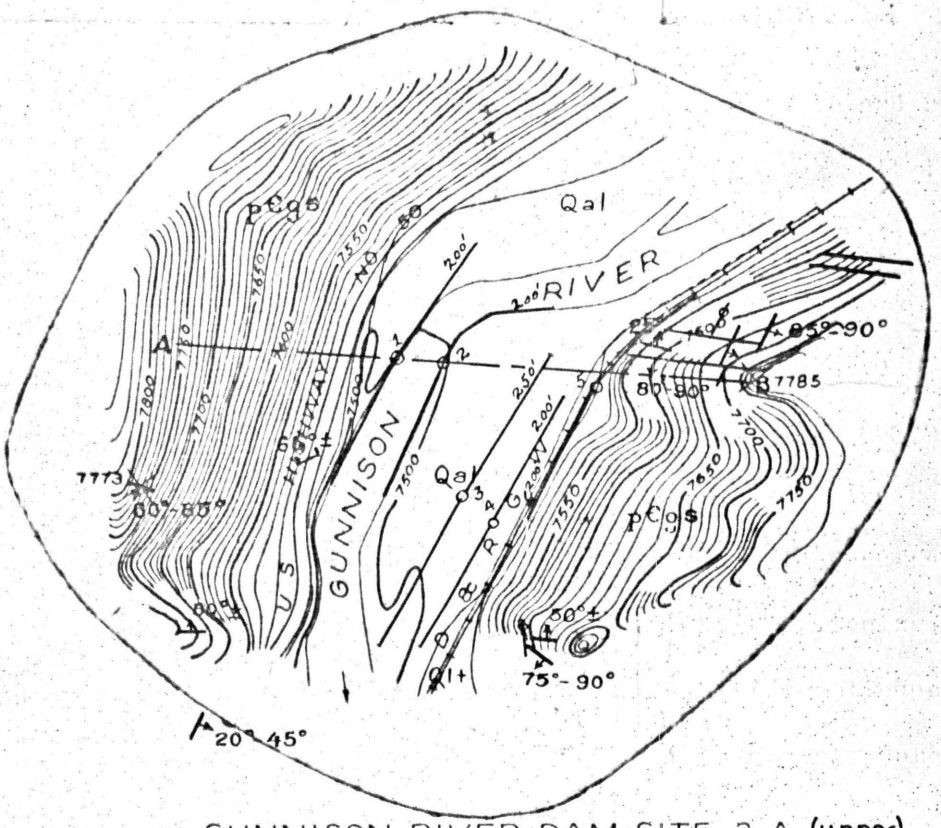
North Beaver Creek Upper Site (# 3-A)

Two of the resistivity lines at this site were located on the dam axis, and the three other lines were positioned with the centers such that the greatest separation of electrodes could be obtained on the area available. Figure 7 shows the positions, direction, extent and the maximum interval of the resistivity lines. Table 3 is the summary of results obtained from the interpretation of the resistivity curves. A sketch of the cross section along the axis, Figure 8, has the bed rock surface indicated by a dotted line from centers 2 to 5, as the intervening depths were projected on the axis to the points where the traverses crossed. The layering, as interpreted from the resistivity curves, that probably exists beneath the centers of the lines is shown in Figure 9.

The indications of the P_1 and P_2 portions of the resistivity curves tend to justify the projection of the depth indications from lines 3 and 4 on the axis, in that the bed rock profile is nearly flat beneath the traverses of these lines.

Line 5 was taken under rather unfavorable topographic conditions along the edge of the D. and R. G. W. R. R. fill adjacent to the abutment wall, and four feet from the center line of the tracks. The line was placed in such a manner to attempt to locate the thick plate of schist mentioned on page

46 by Mr. Piper. Formation tests on the wet granite and schist were not obtainable, but from the dry formation tests it is inferred that probably too little difference exists between the two materials to have sufficient effect to be noted on the types of curves for the site. The granite and schist is also closely intergrown with inclusions which further complicates any attempt to separate the individual effects of each on the curve. From the curve, the spur-like feature above the land surface appears to continue streamward beneath the line beginning with a sharp drop from the 50 to 70 feet interval and continues downward less steeply to about the 120-foot interval where continuous bed rock is indicated.



GUNNISON RIVER DAM SITE 3-A (upper)
MILE 20.7

Figure 7

Plan Scale 1:4800 or 1 inch = 400 feet

400 200 0 400 800 1200 Feet

Contour interval 10 feet

Datum is mean sea level

Location, direction, extent and maximum interval of resistivity lines
North Beaver Creek, Upper Dam Site

Table 3

Summary of interpretations of apparent resistivity curves

North Beaver Creek Upper Dam Site (# 4-C)

Line or Station	Location	Elevation feet	Maximum Electrode Interval feet	Estimated ±10% Depth of fill feet	Thickness of bedrock feet
1.	Right bank, on axis, at water's edge	7500	200	27	>150
2.	Left bank, on axis, at water's edge	7500	200	40	>150
3.	On Qal, see map Fig. 7	7503	250	51	>200
4.	" " " " " "	7503	200	36	>150
5.	37.5 feet upstream from axis, 4 feet E. of R. R. tracks	7515	200	13½*	>150

* see text

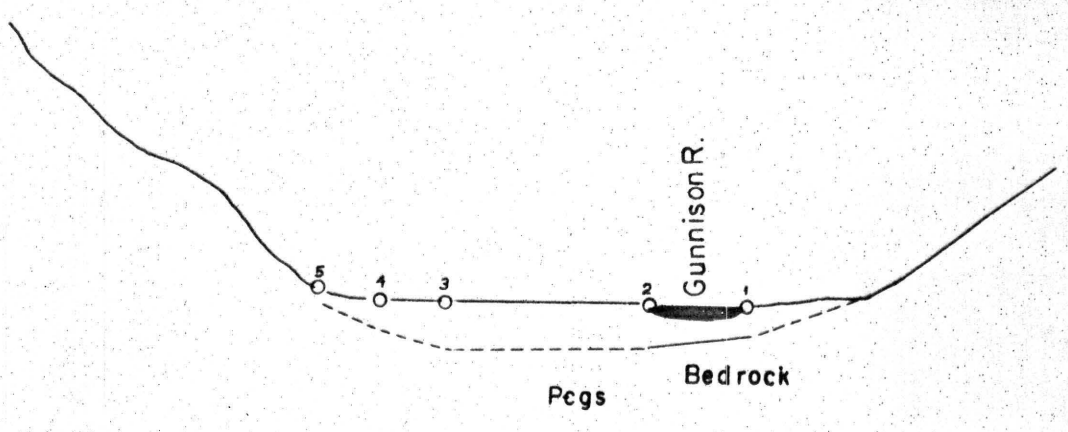


Figure 8

Cross section along axis with bedrock profile

North Beaver Creek, Upper Dam Site (#4 c)

1" = 200'

Layers beneath resistivity line centers

North Beaver Creek, Upper Dam Site (3c)

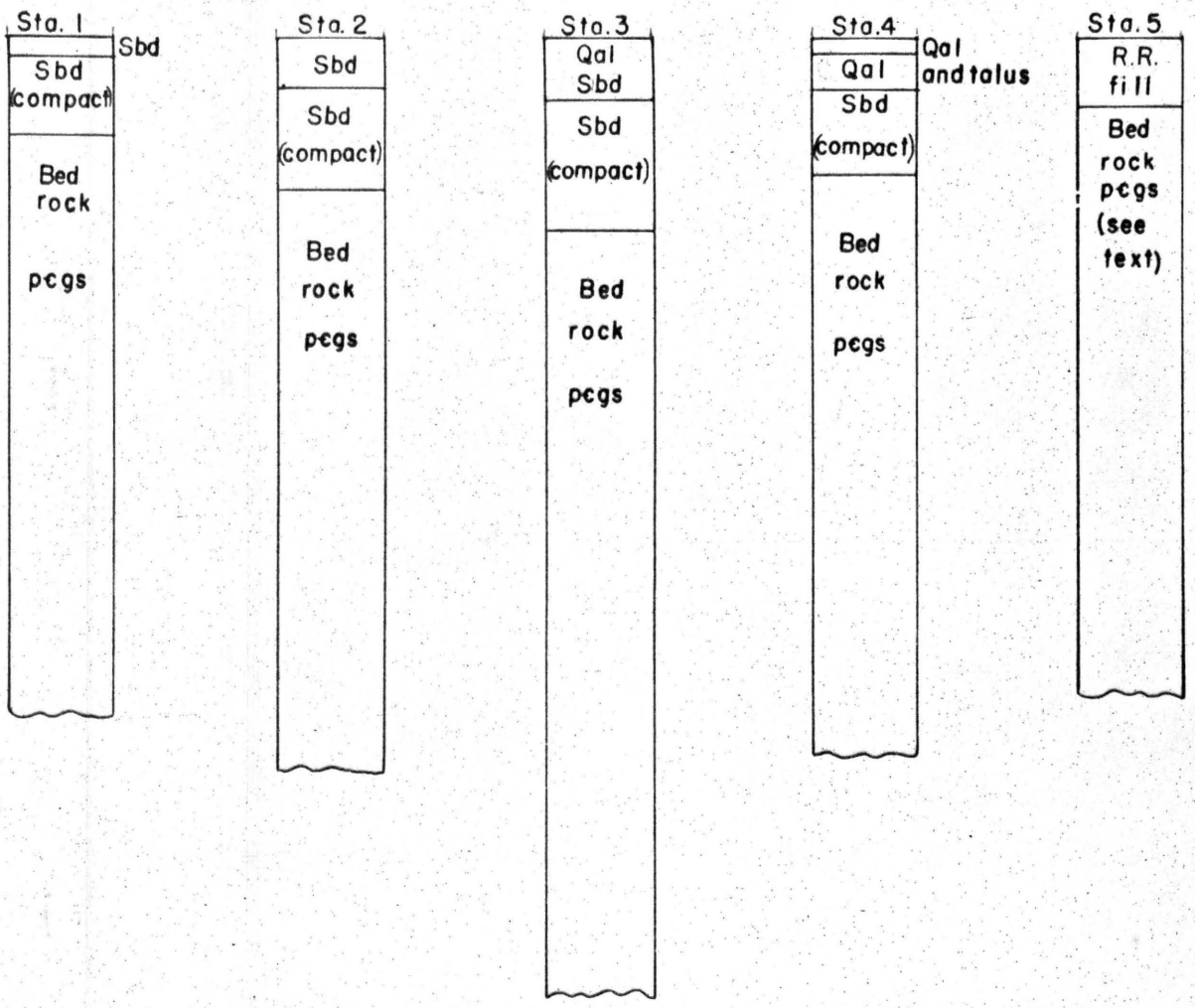


Figure 9
1" = 50'

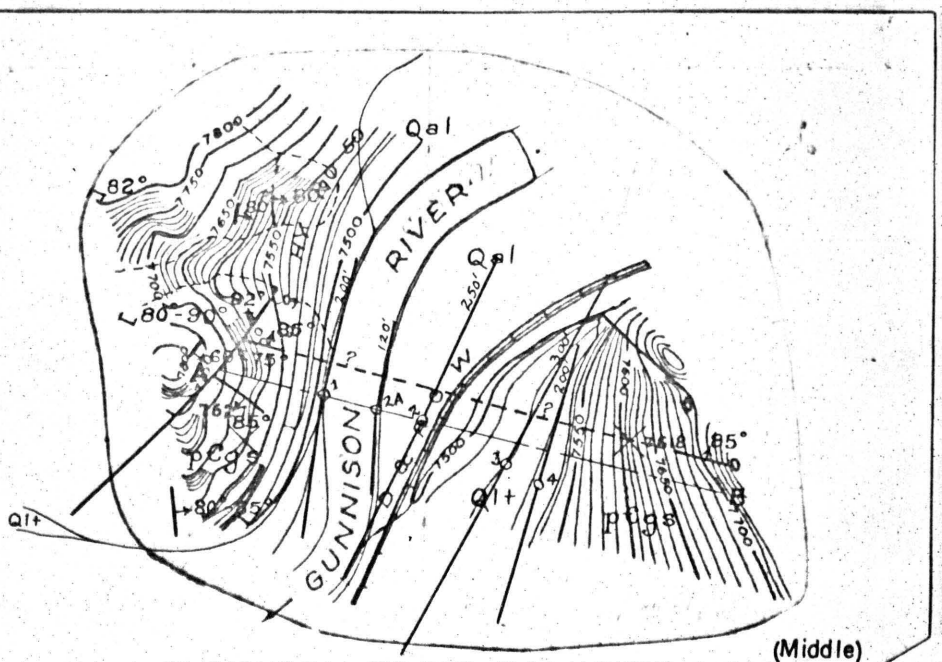
Gunnison River

North Beaver Creek Middle Site (#2)

The five resistivity traverses completed at this site enabled estimates to be made of the thickness of the overburden above the bed rock. Two of the lines were not centered on the proposed axis. The position with respect to the axis, direction, extent and the maximum interval of electrodes for each line is shown in Figure 10. The results from the interpretation of the apparent resistivity curves are summarized in Table 4; and in Figure 12, the probable layers beneath the stations that were estimated from the resistivities of the materials, is shown to scale. In a cross section of the dam site along the proposed axis, Figure 11, the bed rock profile beneath stations 3 and 4 is a dotted line, indicating that the centers of the resistivity lines were not on the axis, and that the depth determinations were projected to the point where the traverse crossed the axis.

The bed rock surface beneath line 1 is estimated to dip downstream. However, as this line was quite difficult to obtain, due to the large amount of recent highway fill along the stream bank, indications other than thickness of overburden from the curves of this line were disregarded. The bed rock beneath line 2, also is estimated to be at a shallower depth upstream from

the center. Along line 4, the bed rock surface as shown by the apparent resistivity curve is dipping downstream, but a zone of discontinuity appears on the upstream curve for the 90 to 140 foot interval that is interpreted to be a thickening of the low terrace and talus overburden. The downstream portion of the curve for line 4, however, appears to be continuous rock.



GUNNISON RIVER DAM SITE NO. 2
MILE 20

Figure 10

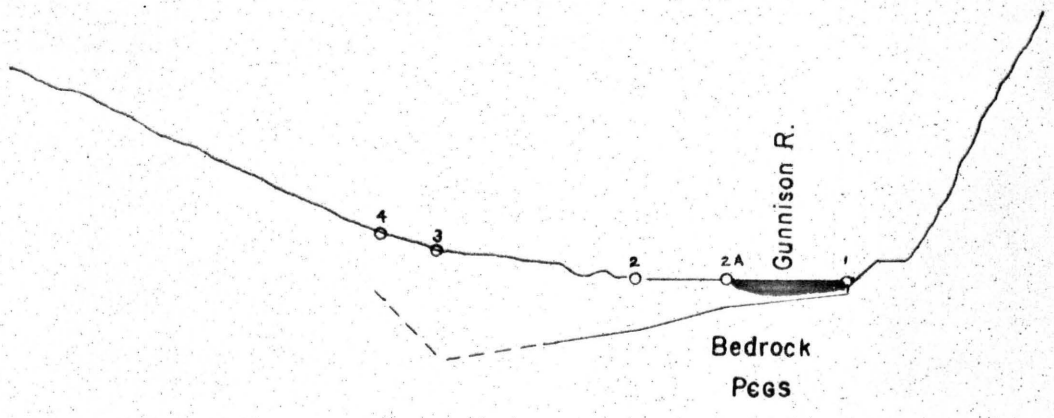
Location, direction, extent and maximum interval of resistivity lines.

Table 4

Summary of interpretations of apparent resistivity curves

North Beaver Creek Middle Dam Site (#2)

Line or Station	Location	Elevation feet	Maximum Electrode Interval feet	Estimated ±10 % Depth of fill feet	Thickness of bedrock feet
1.	Right bank, on axis, at water's edge	7489	200	11	> 100
2A.	Left bank, " " " " "	7489	120	26	> 90
2.	" " , " " , 27.7 feet from R.R. tracks	7495	250	50	> 200
3.	" " , see map, Fig. 10	7520	300	110	> 150
4.	" " , " " , " "	7532	200	60	(see text)



Cross section along axis with bedrock profile

North Beaver Creek, Middle Dam Site (#2)

Figure 11

1" = 200'

Layers beneath centers of resistivity lines

North Beaver Creek Middle Dam Site (#2)

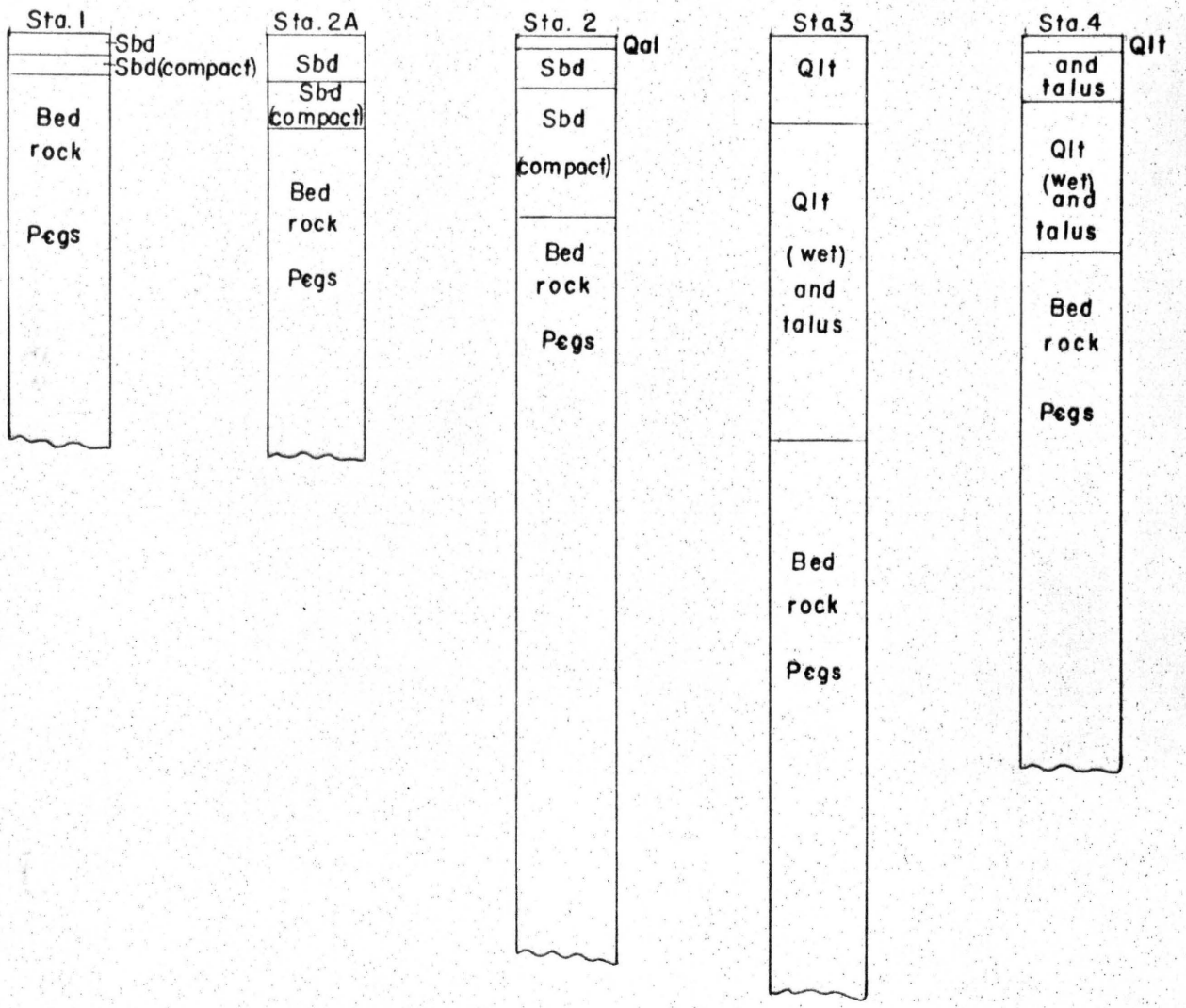


Figure 12

1"=50'

Gunnison River

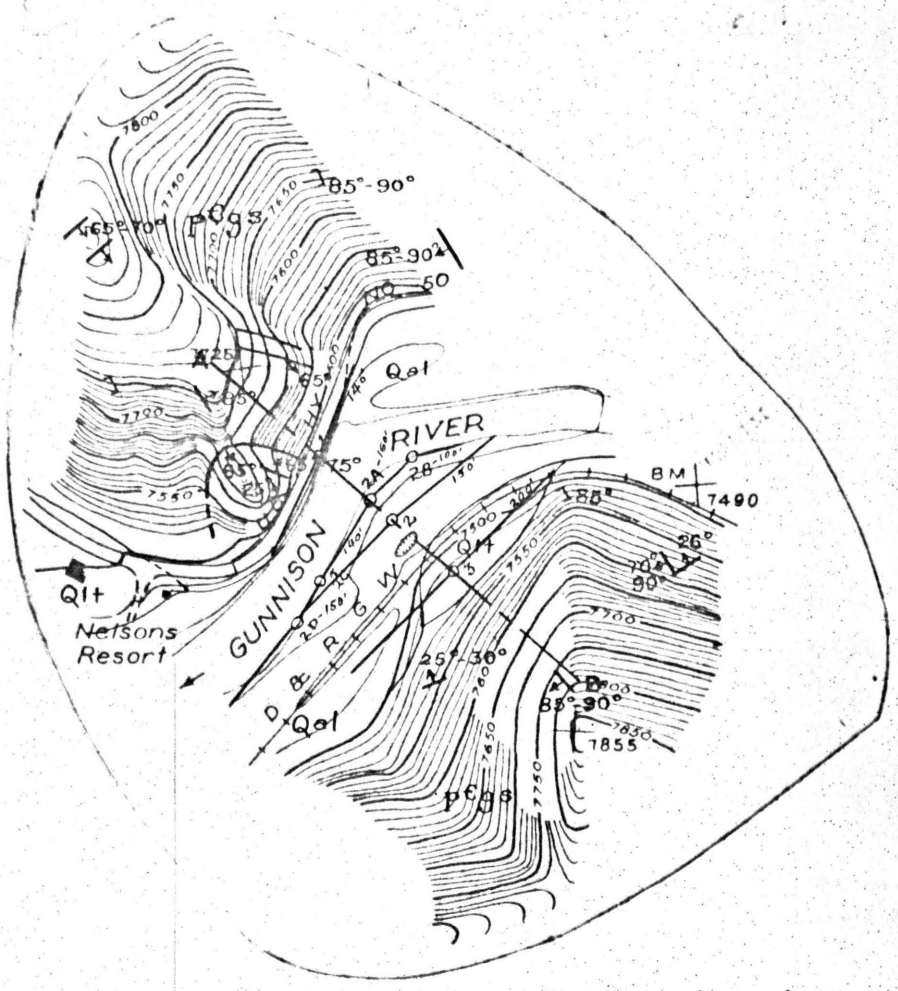
North Beaver Creek Lower Dam Site (# 1A)

In Figure 13, the seven resistivity lines completed at this site are shown as to position, direction, extent and maximum electrode separation. The interpretations of the apparent resistivity curves are summarized in Table 5, with the layers, as estimated from the resistivities of the materials, given to scale in Figure 15. A cross section of the site at the axis is given to scale in Figure 14. Lines 2B, 2C and 2D are omitted from this figure as they were not located on the axis.

It was necessary to locate line 1 along the streamward edge of the U. S. Highway 50, as recent road fill and depth of the river made any other position on the axis near the water's edge impossible. Nevertheless, a smooth curve resulted that gave a good interpretation. A very high conducting layer is present on the curve at an approximate depth of 85 feet, but no such indication appears on the apparent resistivity curves of the left bank, so the exact nature of the material is not known and is assumed to be a local condition, possibly in some way associated with the fractures present downstream from the axis in the right abutment.

Lines 2B, 2A, 2C and 2D were positioned almost perpendicular to the axis in an effort to delineate the granite rib which,

according to Piper, p. 43, crosses the river along the axis. The bed rock surface beneath these lines inclines slightly downstream to the vicinity of line 2D where it flattens and is nearly level. As at the two adjacent upstream sites the resistivities of the granitic rock and the schist is nearly the same value when dry, and probably also when wet, consequently a separation of the two materials on the apparent resistivity curves is very difficult. This condition is further complicated by the extensive areas of inclusion in which the two materials are intergrown. The curves and their associated parts do seem to indicate the general boundaries, provided the wet granite is of higher resistivity; and are tentatively placed upstream from 2B, approximately 50 feet, and downstream from 2C but above 2D. A laboratory study of the electrical properties of the rock samples, both wet and dry, might assist in a better estimate of the boundaries.



GUNNISON RIVER DAM SITE 1-A (lower)
MILE 19.5

Figure 13

Location, direction, extent and maximum interval of resistivity lines

Table 5

Summary of interpretations of apparent resistivity curves

North Beaver Creek Lower Dam Site (# 1 A)

Line or Station	Location	Elevation feet	Maximum Electrode Interval feet	Estimated ±10 % Depth of fill feet	Thickness of bedrock feet
1.	11.5 feet from right bank of stream along edge of road, 9 feet above water	7488	140	15	>100
2.	Left bank, on axis, 75 feet from water's edge	7483	150	44	>100
2A.	" " , " " , 20 " " " "	7479	160	53	>100
2B.	125 feet upstream from 2A, see Figure 13	7479	100	42	> 50
2C.	200 feet downstream " " " " "	7479	140	50	> 90
2D.	300 " " " 2C, " " "	7479	150	54	> 90
3.	On axis, 66.1 feet easterly from R.R. tracks	7512	200	53	>100

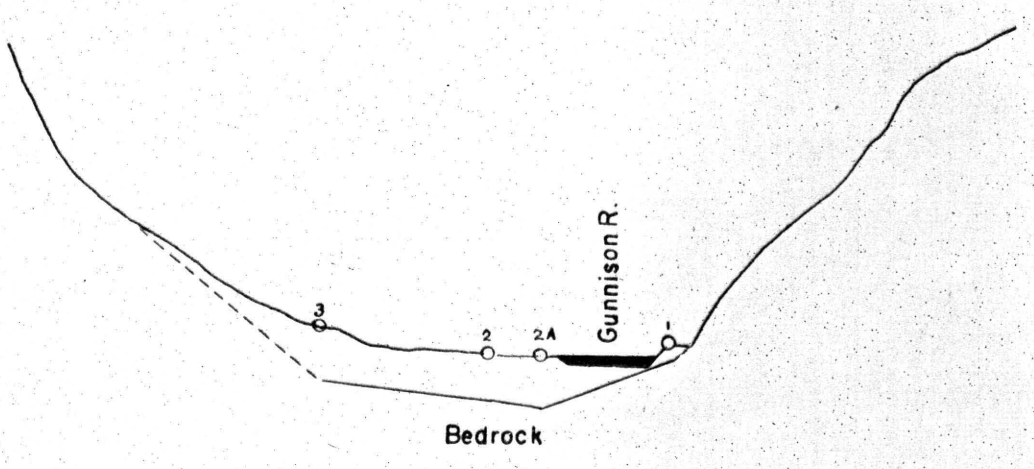


Figure 14

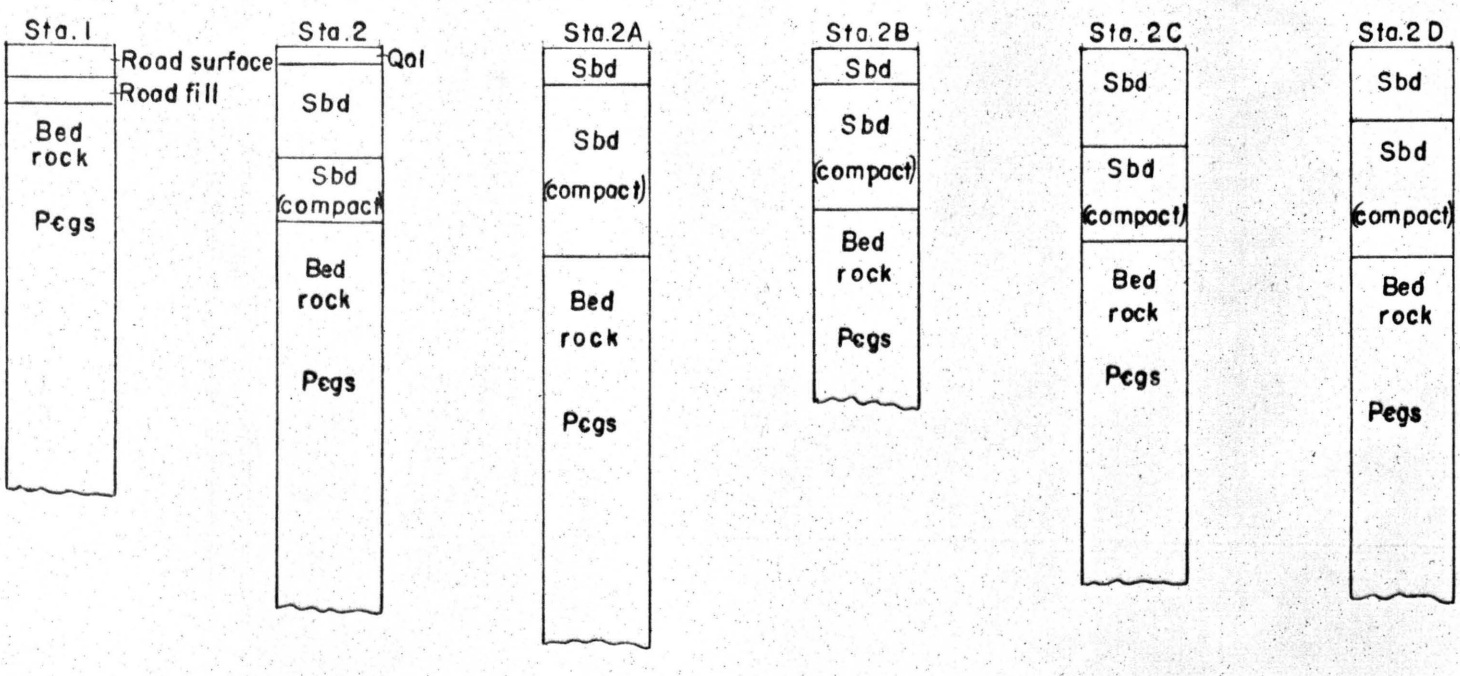
Cross section along axis with bed rock profile

North Beaver Creek, Lower Dam Site (#1A)

1" = 200'

Layers beneath centers of resistivity lines

North Beaver Creek, Lower Dam Site (1A)



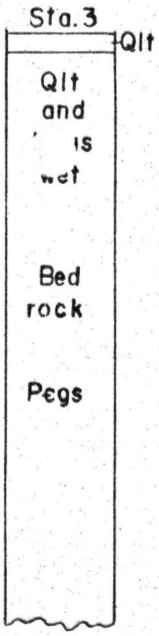


Figure 15

1" = 50'

Gunnison River

Lake Fork Junction Dam Site

The work at this site consisted of six resistivity lines: two at the water's edge; three on the right abutment; and one on the left abutment. The location of the lines with respect to the proposed axis, direction and extent of the electrode line, and the maximum interval is shown in Figure 16.

Table 6 gives the results that were obtained from the interpretation of the apparent resistivity curves. A cross section of the site at the proposed axis, Figure 17, shows the depths to bedrock beneath the several stations of the resistivity lines. Figure 18 shows the probable layers, estimated from the resistivities of the curves, that are beneath each of the resistivity lines.

Lines 2, 2A, and 2B indicate that the surface of the bed rock layer is very irregular with some very rapid thickening of the top layers. No very thick layers of the materials above the gneiss bed rock appear to be present beneath the three lines on the right abutment; the maximum thickness was 27 feet beneath line 2.

Line 4 gives an interpreted depth of about 17 feet to the gneiss bedrock that lies below the high terrace deposit, sandstone and shale members, of which materials about 7 feet is shale. The apparent resistivity curve is irregular beyond the

175-foot interval; and this may indicate either a thickening of the upper low resistance formations, or the very irregular topography over which the observations were made may be the cause.

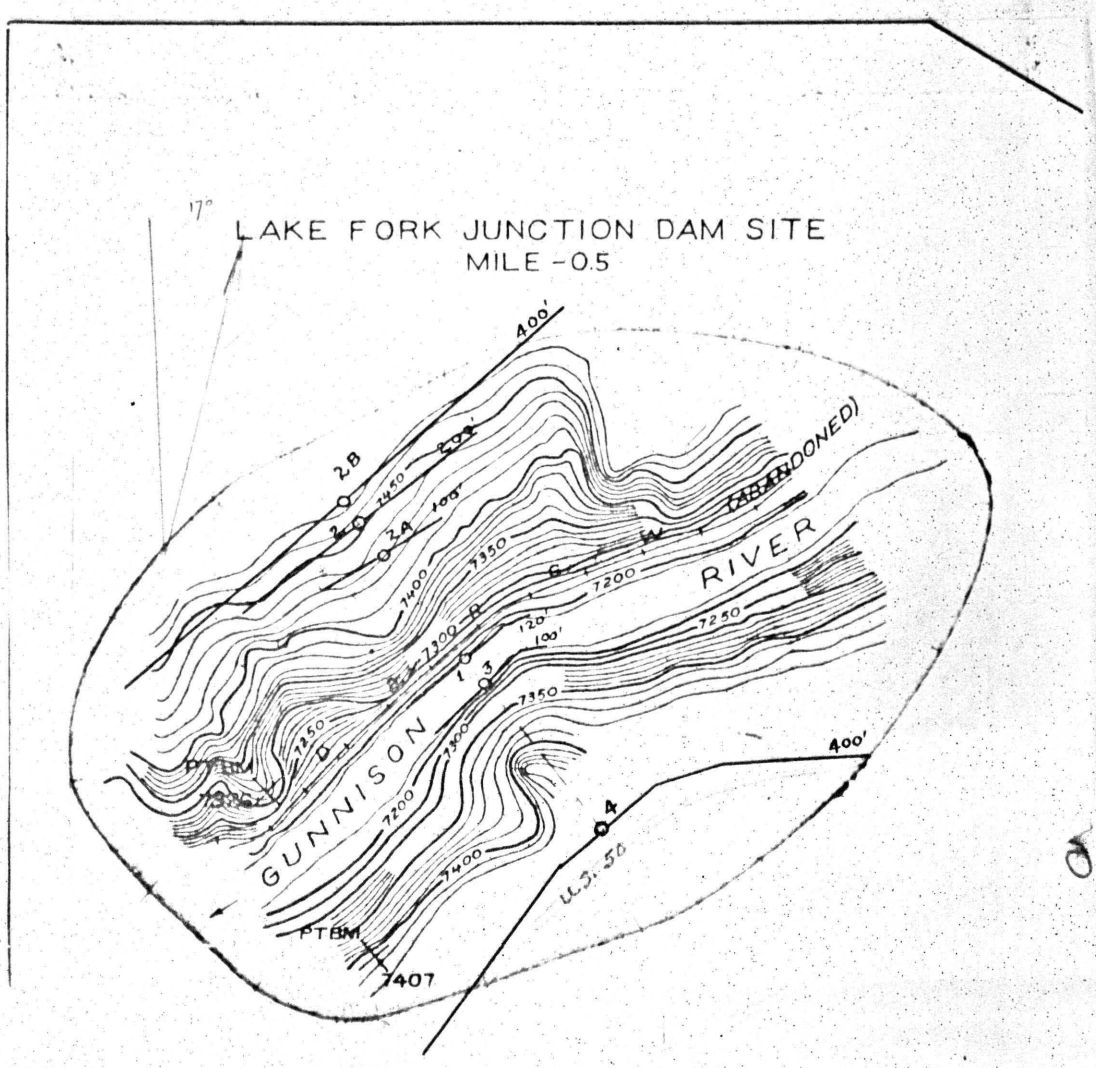


Figure 16

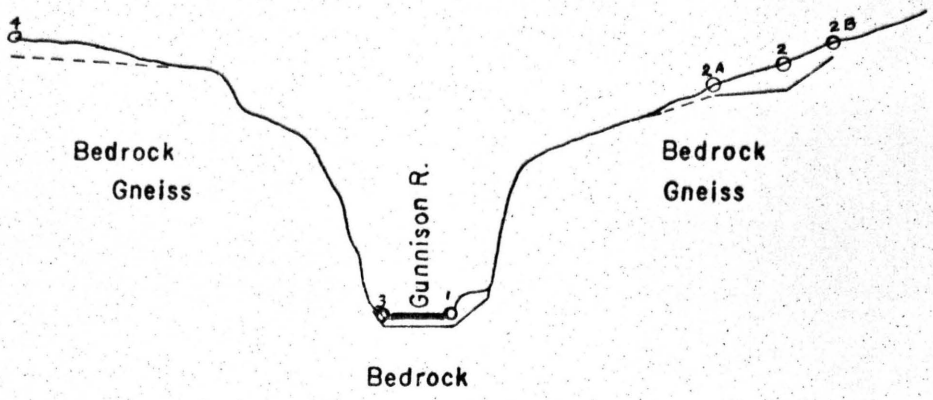
Location, direction, extent and maximum interval of resistivity lines.

Table 6

Summary of interpretations of apparent resistivity curves

Lake Fork Junction Dam Site

Line or Station	Location	Elevation feet	Maximum Electrode Interval feet	Estimated ± 10 % Depth of fill feet	Estimated ± 10 % Thickness of bedrock feet
1.	Right bank, water's edge on dam axis	7195	120	8	> 100
2.	On right abutment	7450	200	27	> 70
2A.	" " "	7430	100	7	- -
2B.	" " "	7470	400	16	>150
3.	Left bank, water's edge, on dam axis	7195	100	8.5	> 90
4.	On left abutment	7480±5	400	17	>100



Cross section along axis with bed rock profile

Lake Fork Junction Dam Site

Figure 17

1"= 200'

Layers beneath centers of resistivity lines

Lake Fork Junction Dam Site

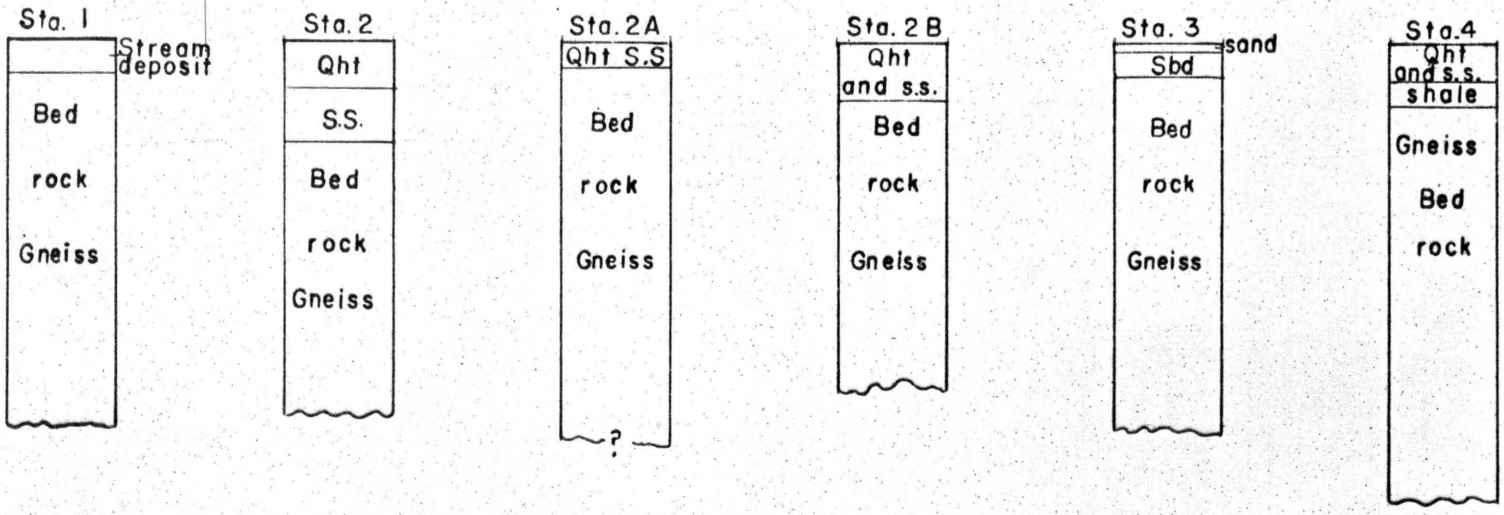


Figure 18

1"= 50'

Lake Fork of Gunnison River

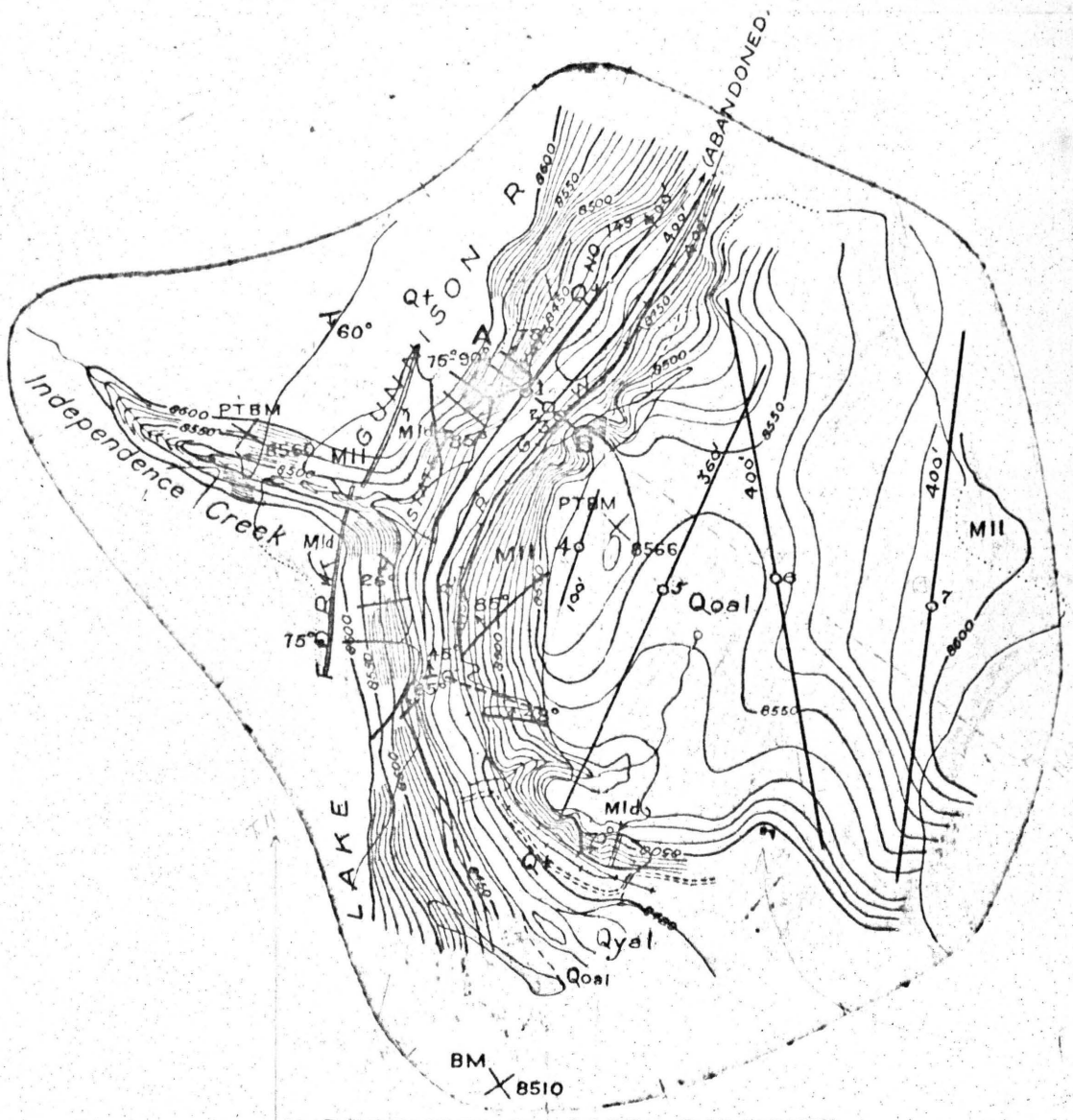
Independence Creek Site

The extent of the resistivity work completed at this site is shown in Figure 19. The center of each line is indicated as to position with respect to the proposed dam axis; the direction of the line of electrodes; the maximum electrode interval, indicated in small figures along the line; and the numbersof the line or station are also on Figure 19.

The results from the interpretation of the resistivity curves are given in Table 7. A cross section along the axis that was prepared from Table 7 and Figure 19 shows the bed rock profile, Figure 20. Lines 4, 5, and 7 are indicated on Figure 20 as if they were on the axis, though actually they are not, thus the dashed line indicating the bed rock surface. The curves indicate a rather good isotropic layering so it is assumed that about the same depths are to be found where the traverse crosses the axis.

No certain identification was made of the rock layer present beneath the quartz latite, and no outcrop downstream from the site was found which, in the opinion of Mr. Pesheck, could be associated with the latite. However, the apparent resistivity curves do indicate that a more resistant material is present at the lower levels reached by these curves.

The probable layers that lie beneath the resistivity lines have been estimated from the curves, and are shown to scale in Figure 21.



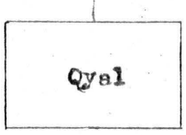
INDEPENDENCE CREEK DAM SITE
MILE 31.8

Figure 19

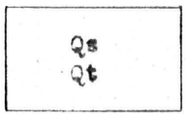
Location, direction, extent and maximum interval of resistivity lines

EXPLANATION

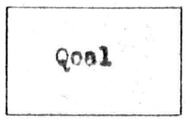
FOR GEOLOGIC MAPS OF DAM SITES ALONG LAKE FORK OF THE GUNNISON RIVER, COLORADO.



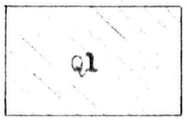
STREAM-BED AND FLOOD-PLAIN DEPOSIT
(sand, gravel and cobbles)



SLOPE WASH(Qs) AND TALUS(Qt)

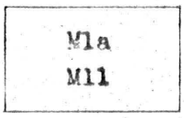


TERRACE DEPOSIT
(sand and gravel with cobbles and boulders as much as 18 inches in diameter)



LANDSLIDE RUBBLE
(unassorted debris of all sizes up to blocks 10 feet long)

RHYOLITE (?) DIKES

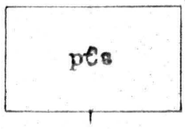


ANDESITE (Mla) AND QUARTZ LATITE (Mll)

ANDESITIC PYROCLASTICS
(agglomerate, tuff, scoria, and pumice)

LAKE FORK ANDESITE

GREAT UNCONFORMITY



AMPHIBOLITE SCHIST

STRIKE AND DIP OF BEDDING

STRIKE AND DIP OF SCHISTOSITY

TRACE AND DIP OF INCLINED FRACTURE

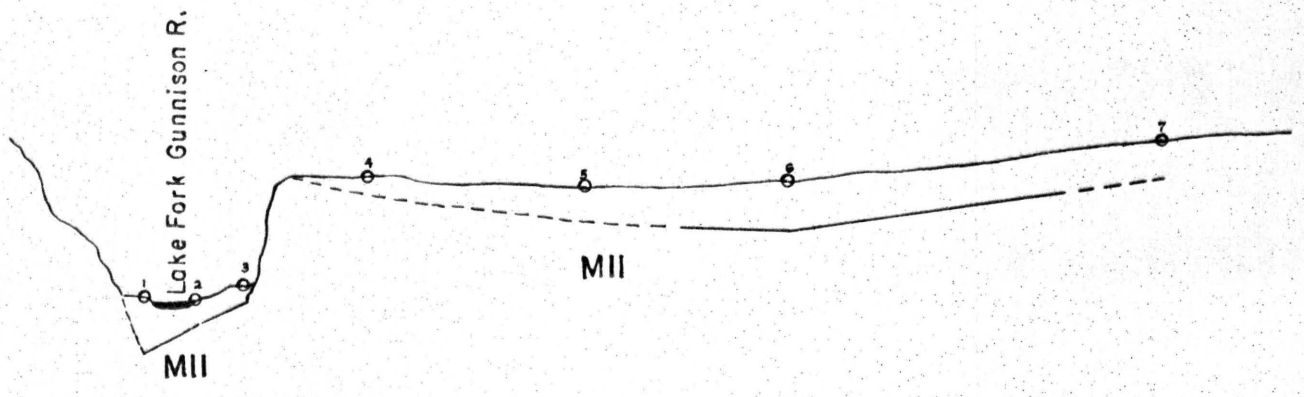
SUGGESTED POSITION OF DAM

Table 7

Summary of interpretations of apparent resistivity curves

Independence Creek Dam Site

Line or Station	Location	Elevation feet	Maximum Electrode Interval feet	Estimated ±10% Depth of fill feet	Estimated ±10% Thickness of bedrock feet
1.	Along stream-edge of road, left bank, on axis	8437	400	59	> 260
2.	Water's edge, right bank, on axis	8432	400	26	> 100
3.	50 feet from stream on R. R. fill, on axis	8447	400	15	> 100
4.	On right abutment, 201.5 feet upstream from axis, 135 feet from escarpment	8563	100	17	> 60
5.	On right aburment, 172 feet E. 25° S(mag.) from B.M. (8566), not on axis	8545	360	37	> 200
6.	379 feet from B.M. (8566), right abutment, on axis	8555	400	50	> 200
7.	326.5 feet from line 6, 151.5 feet ⊥ to axis, downstream, not on axis	8594	400	38	> 100



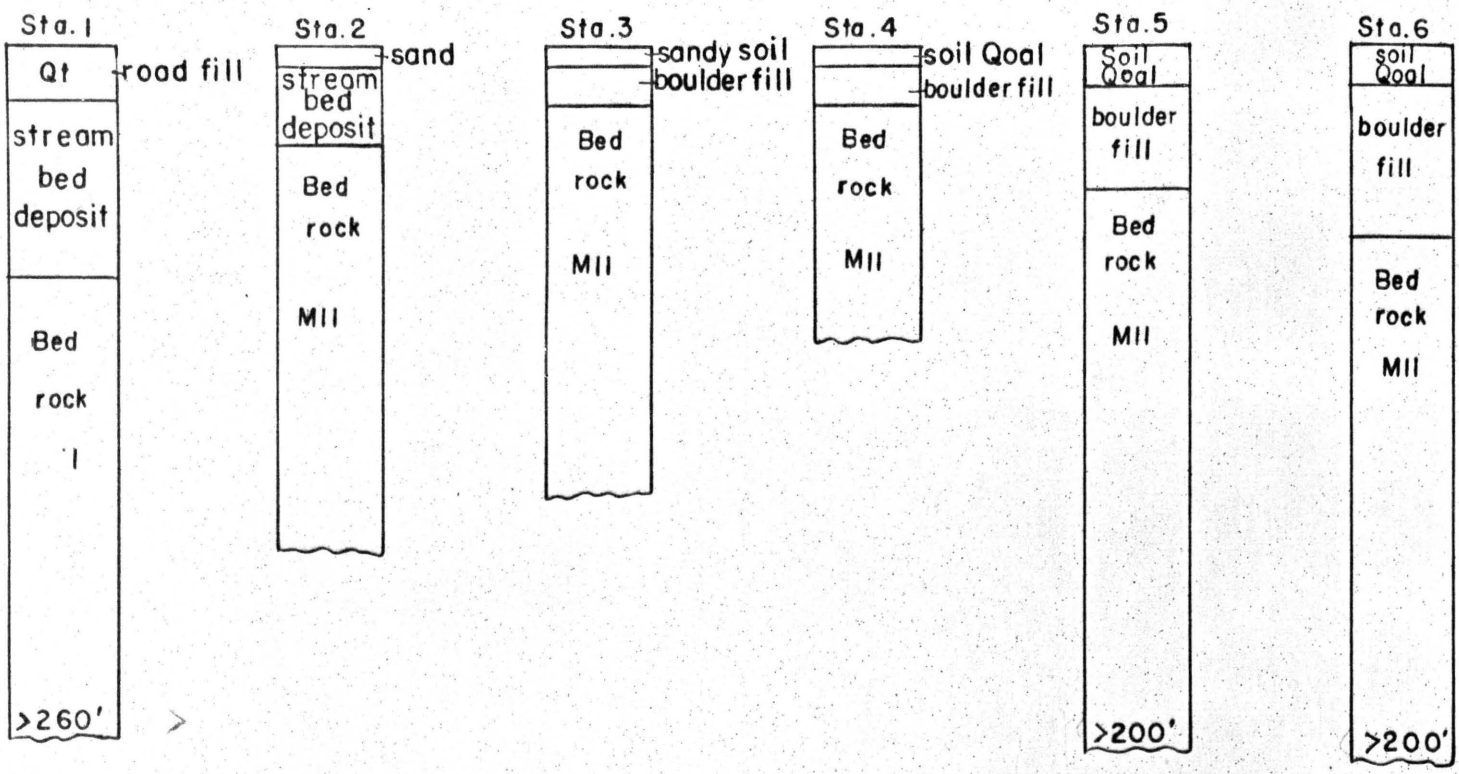
Cross section along axis with bed rock profile

Independence Creek Dam Site

Figure 20
1"=200'

Layers beneath centers of resistivity lines

Independence Creek Dam Site



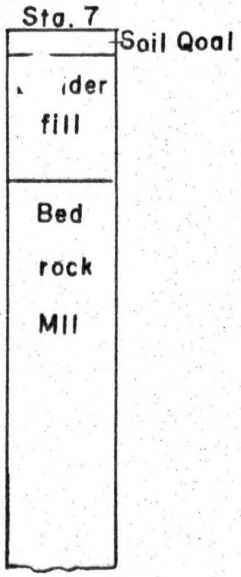


Figure 21
1"=50'

Lake Fork of Gunnison River

The Gates Dam Site

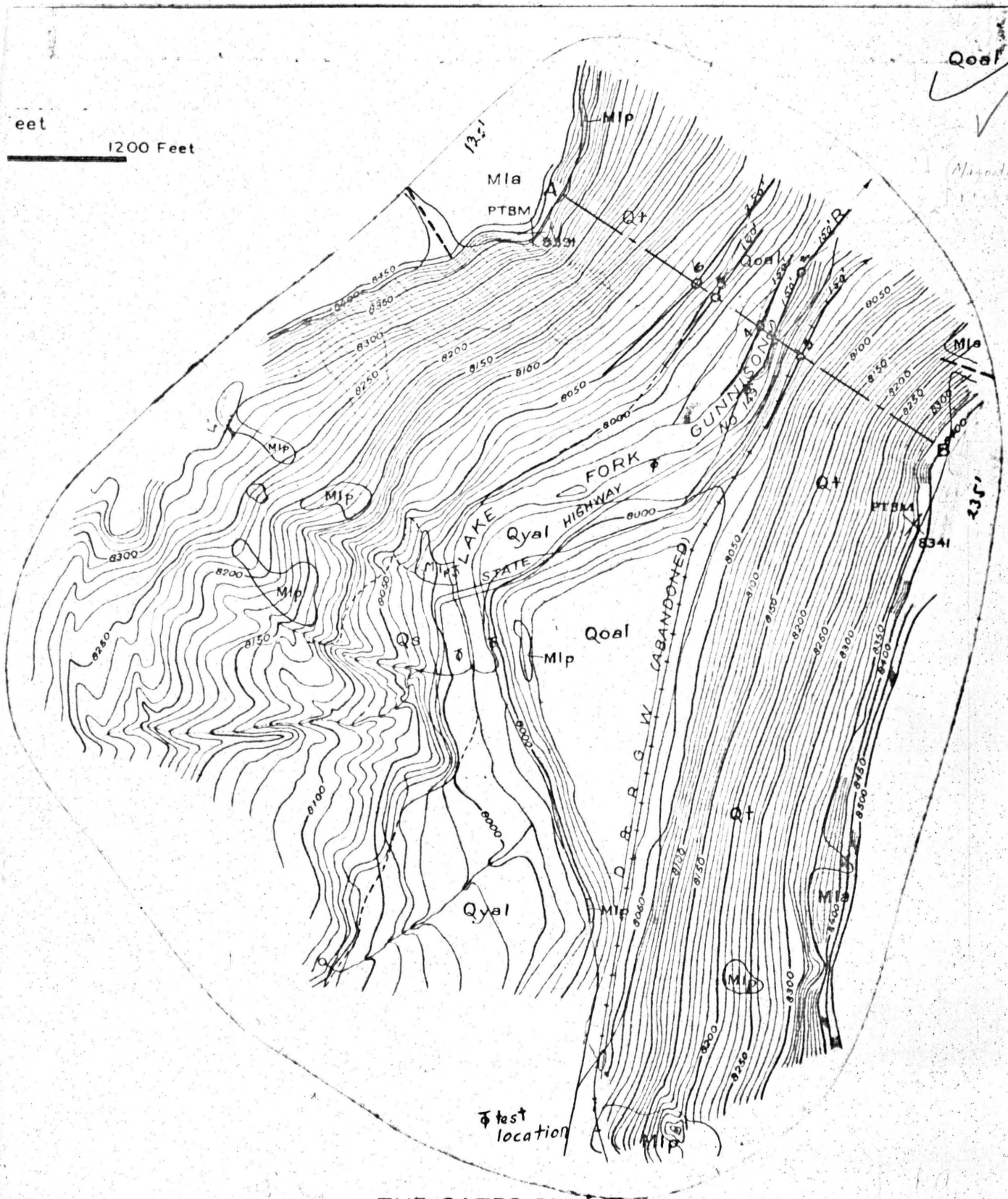
The lines completed at this site, the position with respect to the proposed axis, the direction, and the maximum electrode interval, are shown in Figure 22.

The results obtained from the interpretation of the resistivity curves are tabulated in Table 8. By means of Figure 22 and Table 8, Figure 23 was constructed and shows the bed rock profile beneath the site. The very loose nature and the size of the talus Qt made resistivity lines impractical farther up the slope of the abutments.

Two horizontal discontinuities in the bed rock appear on the upstream portion of the curve from the center of line 1; 20 to 40 feet intervals, and 60 to 90 feet intervals; that indicate the possible thickening of the alluvium in this direction. The downstream portion of the curve, however, is more uniform and a depth estimate is also given for this part of the curve. Line 2 was in a material of very low resistance and samples of the rocks were brought in for examination. Charles Milton of the Chemistry and Physics Section reports that they contain considerable magnetite and ilmenite, sufficient to be attracted strongly to a magnet, and thus would have a low resistance. Line 4 indicates a horizontal discontinuity between the 70 to 100 foot interval with a corresponding thickening of the over-

burden. A similar condition appears on line 5 for the 50 to 100 feet interval with the more pronounced thickening of the overburden upstream from the center that may increase the thickness 10 to 20 percent more than is given in Table 2.

The thickness and character of the formations beneath the lines have been estimated from the curves and is given in Figure 24.



THE GATES DAM SITE
MILE 19.4

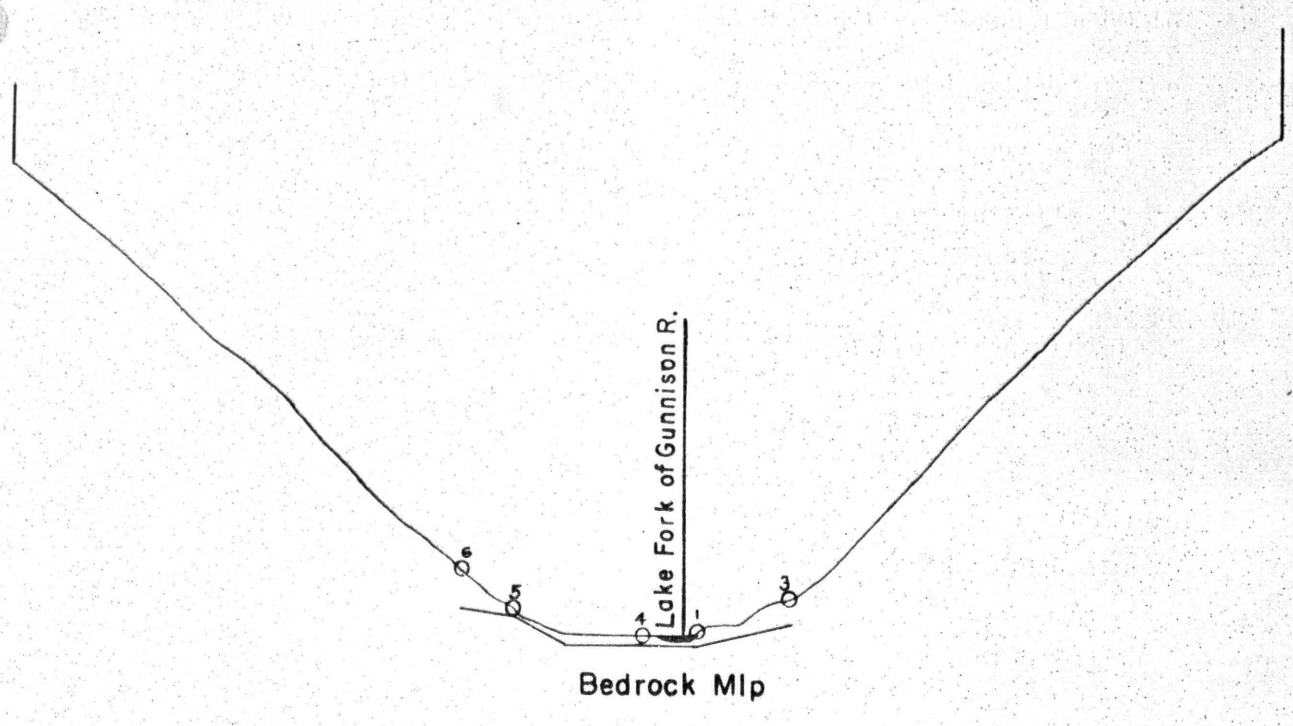
Figure 22
Location, direction, extent and maximum interval of resistivity lines

Table 8

Summary of interpretations of apparent resistivity curves

The Gates Dam Site

Line or Station	Location	Elevation feet	Maximum Electrode Interval feet	Estimated ±10 % Depth of fill feet	Estimated ±10 % Thickness of bedrock feet
1.	Right bank along water's edge on axis	7879	150	8	> 140
1-P_2.	" " " " " " "	7879	150	10	> 140
2.	Right bank, water's edge, 200 feet down from axis	7878	150	8	> 140
3.	Right abutment along old R. R. grade	8020	150	28	> 120
4.	Left bank, 15 feet from water's edge	7881	150	10	> 140
5.	Left bank, 150 feet from stream on 8020 contour	8020	160	6	> 150
6.	Left abutment between 8050-60 contour	8055	250	40	> 140



Bedrock Mlp

Figure 23

Cross section along axis with bed rock profile

The Gates Dam Site

1" = 200'

Layers beneath centers of resistivity lines

The Gates Dam Site

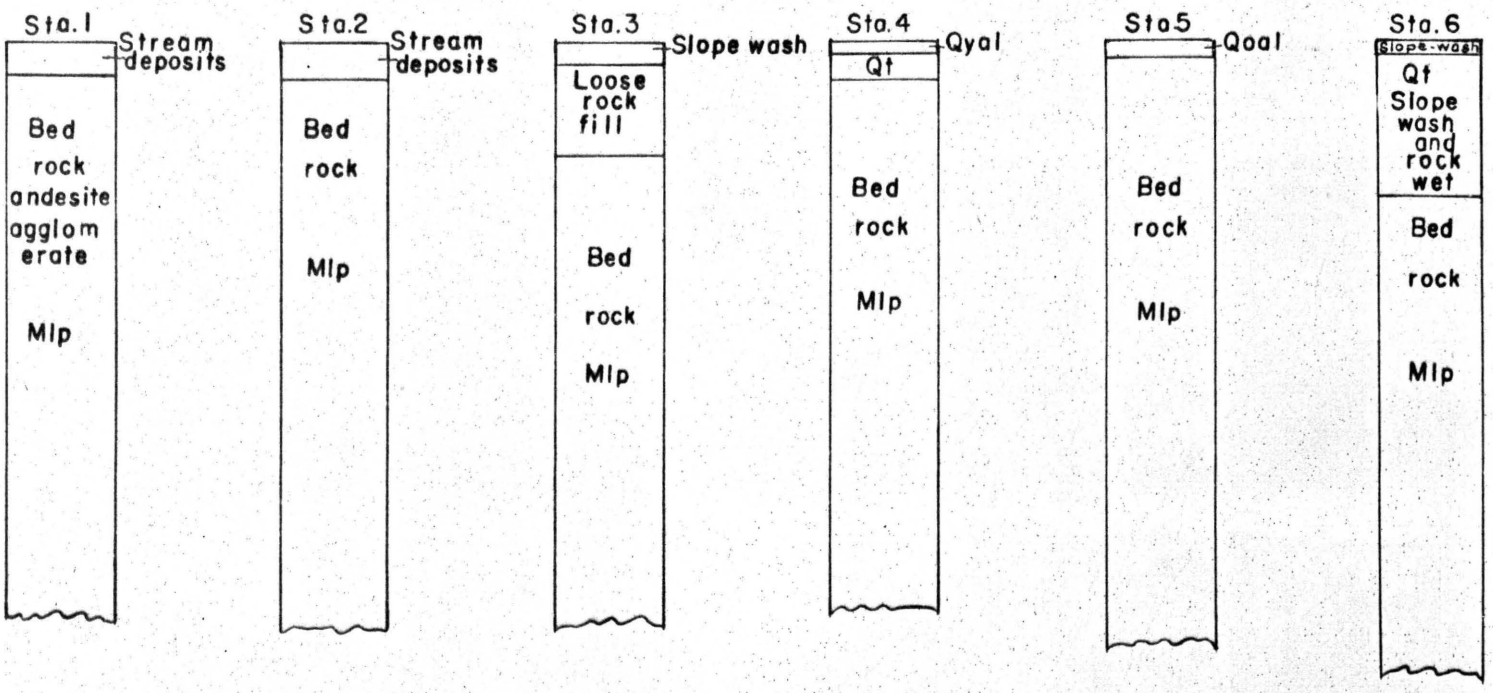


Figure 24

1" = 50'

Lake Fork of Gunnison River

Riverside School Site

Six resistivity lines were completed at this site, and the position on the axis, direction, maximum electrode interval, and the extent of the lines are shown in Figure 25.

The results obtained from the interpretation of the apparent resistivity curves are given in Table 9. A cross section along the proposed dam axis is shown in Figure 26 and was constructed from the results in Table 9 and the Figure 25. The probable layers were estimated from the resistivities and are shown for each of the lines in Figure 27.

The bed rock at this site is estimated to be similar to that encountered at the Gates site approximately 5 miles upstream, and has an apparent resistivity of about the same value. Best interpretations were obtained from the curves for lines 2, 3, and 5.

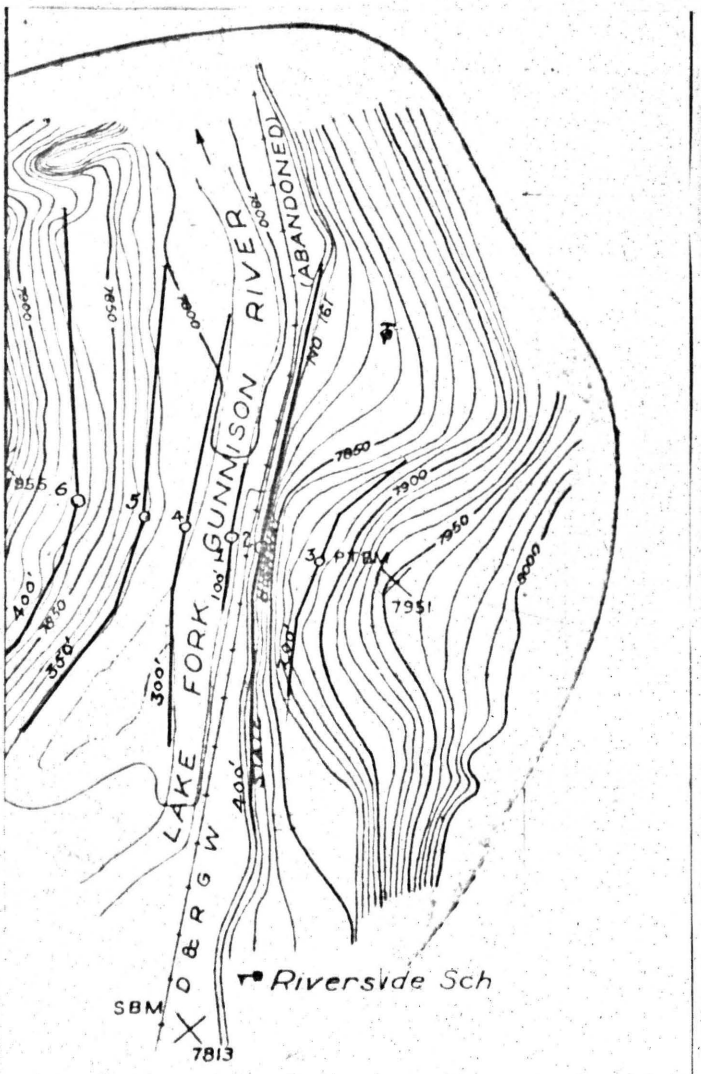


Figure 25

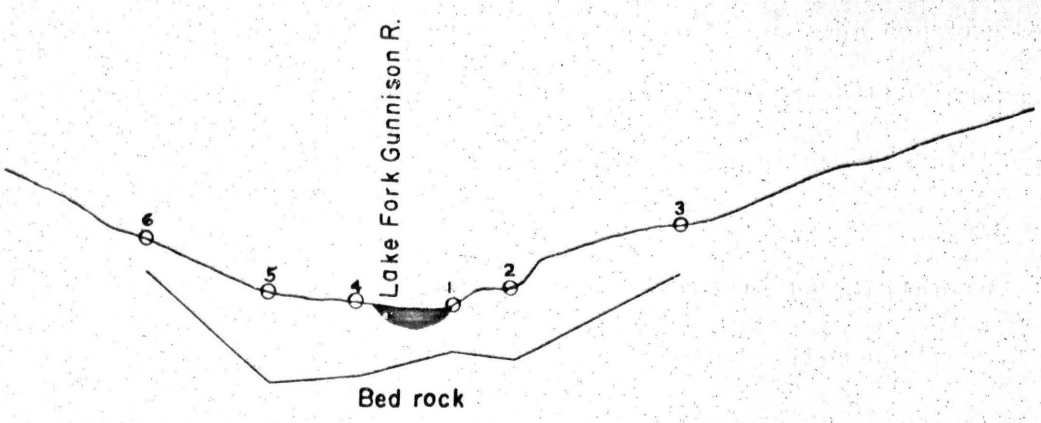
Location, direction, extent and maximum interval of resistivity lines

Table 9

Summary of interpretations of apparent resistivity curves

The Riverside School Dam Site

Line or Station	Location	Elevation feet	Maximum Electrode Interval feet	Estimated ± 10 % Depth of fill feet	Estimated ± 10 % Thickness of bedrock feet
1.	Right bank, water's edge on dam axis	7802	100	44	~ 60
2.	Easterly from road center 20 feet, on axis	7822	400	75	~ 300
3.	On right abutment, center on axis, 7830-90 contour	7837	200	49	150
4.	Left bank, 18 feet from water's edge, on axis	7803	300	73	225
5.	Left bank, 116 feet from stream, on axis	7820	350	35	250
6.	On left abutment, 143.5 feet from line 5, center on axis	7875	400	27	300



MII

Figure 26

Cross section along axis with bed rock profile

Riverside School Dam Site

1" = 200'

Layers beneath centers of resistivity lines

Riverside School Dam Site

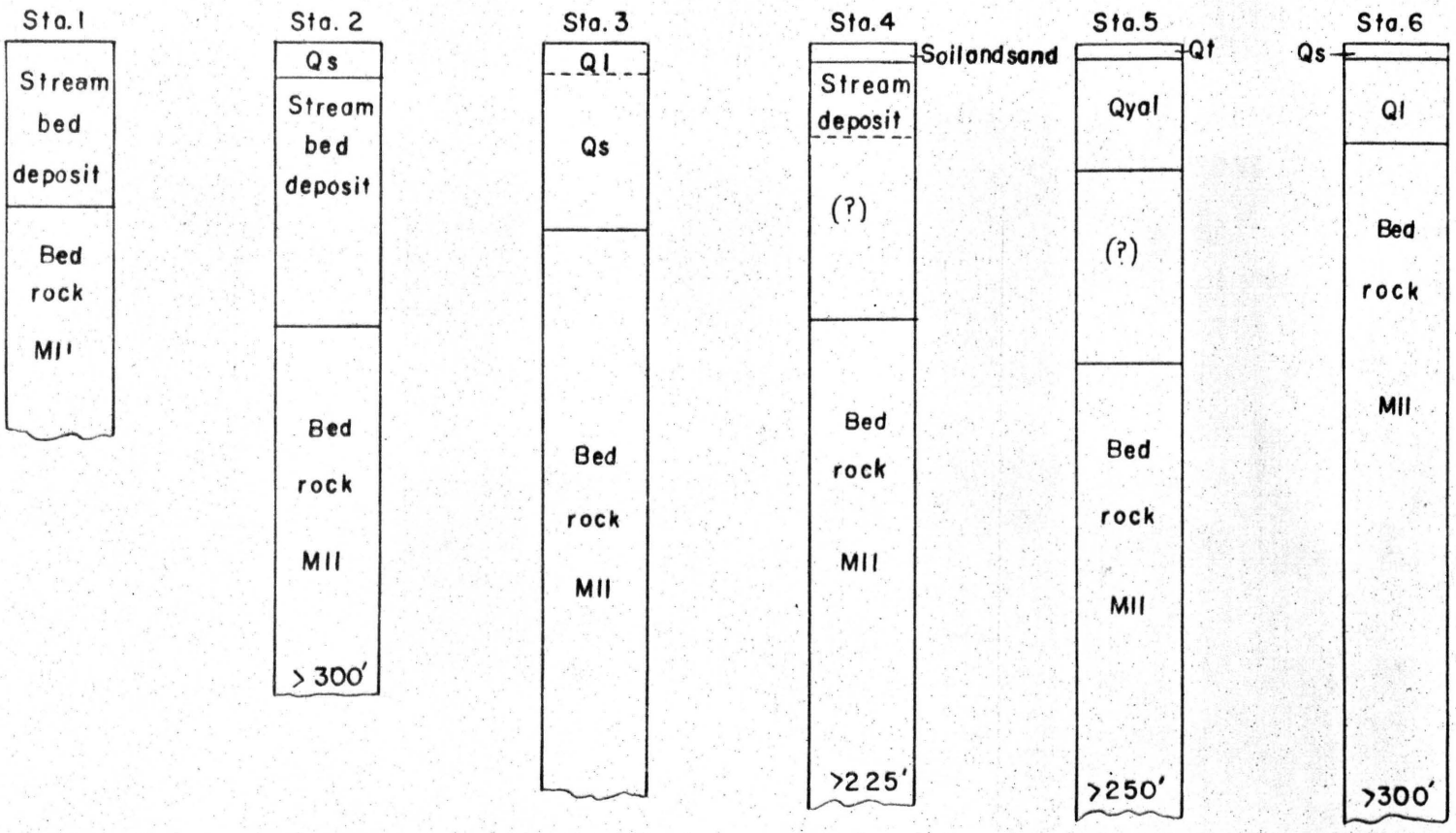


Figure 27

1"=50'

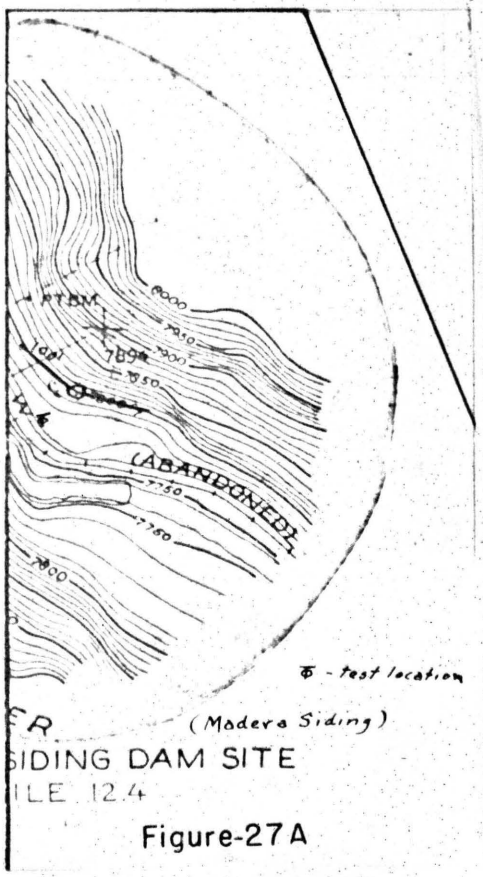
Lake Fork of Gunnison River

Madera Siding Site

The resistivity work at this site consisted of making a formation test on the siliceous amphibolite schist, both along and across the foliation; and a short line, 100 feet maximum interval, with the center on the 7800 contour, 100 feet upstream from the line joining the B. M.'s and on the right abutment as shown on Figure 27A.

This point is located about 20 feet downstream from the larger talus area on the right bank, Plate 25 of Piper's report, so that the downstream portion of the line is over schist and the upstream part is over talus with the exception of the first 20 feet.

The curve obtained offers only a qualitative interpretation that agrees well with the position of the line, in that continuous rock appears downstream and talus upstream from the center of the line. The schist is discontinuous from about the 30-foot interval upstream to the last interval obtained, 100 feet, and the talus may thicken, though the amount is not ascertainable from the curve. The topography was such that a longer line was impractical.



ER
SIDING DAM SITE
ILE 12.4

Figure-27A

Location, direction, extent and maximum interval of resistivity lines

Little Colorado River

Little Colorado River Dam Site

The position of the twenty-five resistivity lines along the two proposed axes at this site, together with the direction, and extent of the lines are shown in Figure 28.

The interpretations from the apparent resistivity curves are given in summarized form in Table 10 for axis AB, and Table 11 for axis CD.

A cross section along the proposed dam axis AB is shown in Figure 29, with the depths to bed rock beneath the centers of the resistivity lines that were located on the axis. Toe and heel depths may be taken from Table 10 for comparison.

A similar cross section along dam axis CD is shown in Figure 30 for the four resistivity lines centered on the axis that determine the depth of fill. Comparative toe and heel depths may be obtained from Table 11.

The layers beneath each resistivity line have been estimated from the apparent resistivity curves, and are shown in Figure 31, with the exception of Station 12.

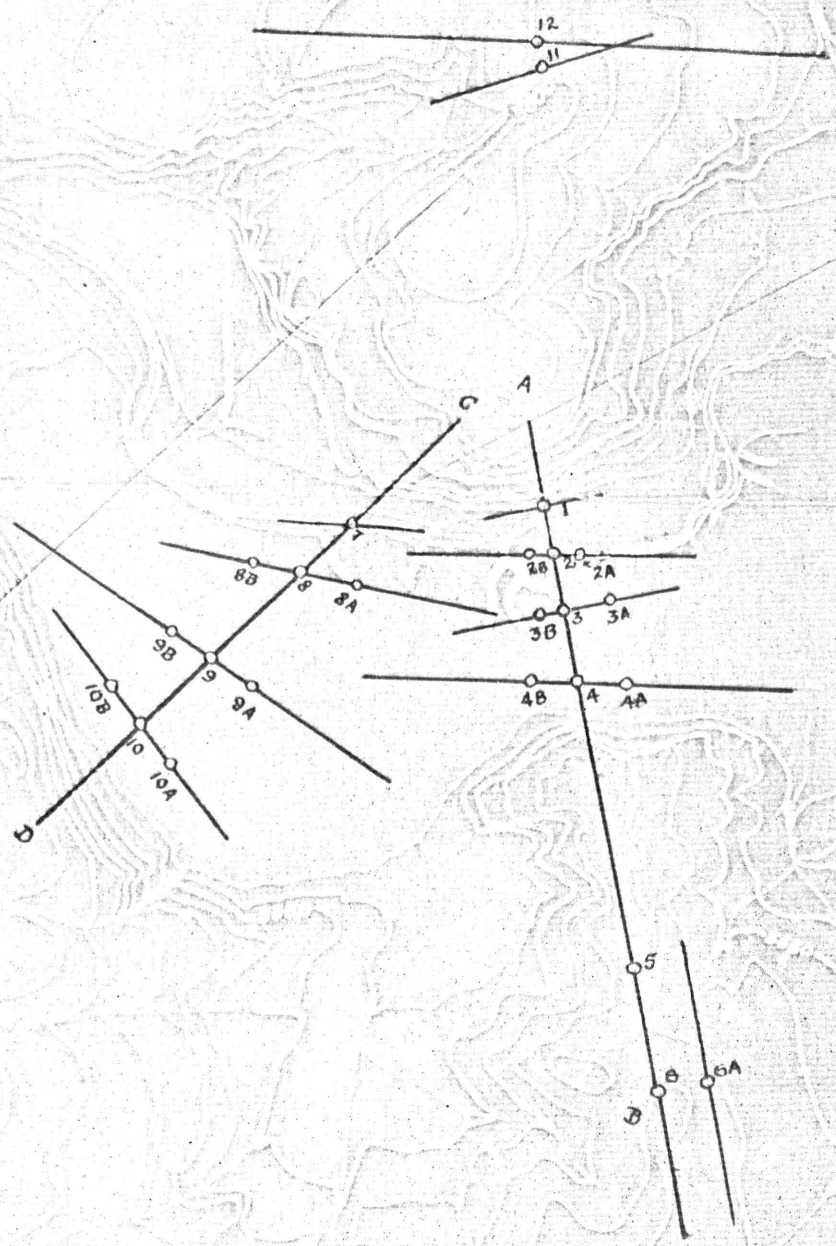
Some horizontal discontinuities of the bed rock layers show markedly on the "full" resistivity curves as well as upon its two component parts, P_1 and P_2.

Along axis AB, line 4 shows a horizontal discontinuity of the bed rock layer, Trm, from the 120-foot to 200-foot interval

and again between the 250-foot and 300-foot interval on the P_1 portion of the curve, and another on the P_2 curve from the 120-foot to 160-foot interval. These variations are more pronounced on the curves of lines 4A and 4B. All of the above discontinuities are small and, at most, increase the depth of fill only a few feet, probably less than 10 percent of the thickness of the overburden. Lines 5, 6, and 6A indicate that the bed rock formation, Trm, is continuous under the extent of the resistivity traverses, with the exception of some small horizontal discontinuities that increase the thickness of the terrace deposit, Qtg, at a few places along the resistivity line.

Axis CD, the alternate axis, also has some horizontal discontinuities with a corresponding thickening of the overburden. Line 8 indicates such a discontinuity from the 90-foot to 120-foot intervals on the P_1 curve, and is more apparent from the curves of 8A. Depth to bedrock may be 10 - 20 percent more than is indicated for the complete curves along this portion of the traverse. Line 9 indicates discontinuties on P_1 from the 100-foot to 180-foot intervals and the 250-foot to 300-foot intervals; on P_2, from the 120-foot to 160-foot intervals, and the 230-foot to 280-foot intervals. The effect of the variations of the bed rock surface is more apparent from lines 9A and 9B, and here the overburden may be as much as 10 to 20 percent thicker beneath the discontinuous portion of the resistivity line than is indicated for that beneath the center of the line.

Resistivity lines 11 and 12 are on the terrace deposit, Qtg, of the right abutment near "E" of Plate 27 in Mr. Piper's report. A horizontal discontinuity on P_2 of line 11, from 70 feet to 160 feet, the maximum practical interval, indicates the thickening of the terrace deposit down the contour of the ravine. The Trm formation appears to be continuous on the resistivity curve, however, in the upstream direction. The apparent resistivity curves for line 12 are rather complex and have been analyzed in a qualitative manner, and the results are given diagramatically in Figure 32.



Location, direction, extent, and maximum interval of resistivity lines

Figure 28

Table 10

Summary of interpretations of apparent resistivity curves

Little Colorado River Dam Site Axis AB

Line or Station	Location	Elevation feet	Maximum Electride Interval feet	Estimated 10% Depth of fill feet	Estimated 10% Thickness of bedrock feet
1.	Right bank of stream - 6 feet from normal water's edge, on the axis	5513	70	4.5	> 60
2.	Left bank, 40 feet from water's edge, 94 feet from line 1, on the axis	5525	200	18	> 130
2A.	50 feet upstream from axis on line 2	5525	120	18	100
2B.	50 feet downstream " " " " 2	5525	100	20	80
3.	Left bank, 219 feet along axis from line 1	5525	100	16	80
3A.	100 feet upstream from axis on line 3	5525	100	18	80
3B.	50 feet downstream " " " " 3	5525	120	22	100
4.	Left bank, 364 feet along axis from line 1, 40.1 feet from B.M. (5523 elev.)	5525	300	33*	> 250
4A.	100 feet upstream from axis on line 4	5525	200	31*	> 150
4B.	100 feet downstream " " " " "	5525	160	31*	125
5.	Top of left abutment, 440 feet along axis from B.M. (5577 elev.)	5577	275	12*	100
6.	Top of left abutment, 700 feet along axis from B.M. (5577 elev.)	5580	200	22*	150
6A.	100 feet E and N. from center of line 6	5573	200	4½*	90

* See text

Table 11

Summary of interpretations of apparent resistivity curves

Little Colorado River Dam Site Axis CD

Line or Station	Location	Elevation feet	Maximum Electrode Interval feet	Estimated ± 10% Depth of fill feet	Estimated ± 10% Thickness of bedrock feet
7.	Left bank, water's edge, on axis	5510 ±	100	17	80
8.	Left bank, 150 feet along axis from line 7	5525 ±	200	31	170
8A.	125 feet upstream from axis along line 8	5525 ±	200	26*	175
8B.	100 feet downstream " " " " "	5525 ±	100	21	80
9.	Left bank, 400 feet along axis from line 7	5525 ±	300	35*	250
9A.	100 feet upstream from axis along line 9	5525 ±	160	23.5*	125
9B.	100 feet downstream " " " " "	5525 ±	300	35*	250
10.	Left bank, 600 feet along axis from line 7	5525 ±	200	21	175
10A.	100 feet upstream from axis along line 10	5525 ±	100	18	75
10B.	100 feet downstream " " " " "	5525 ±	100	19	75
11.	Right abutment, W. 700 feet along line of B.M.s from B.M. 5539 elev., thence N. 25° W.(mag.) 100 feet	5595	160	10.5*	75
12.	Right abutment, W. 750 feet along line of B.M.s from B.M. 5539 elev., thence N. 25° W. (mag.) 100 feet	5600	400	22*	- -*

* See text

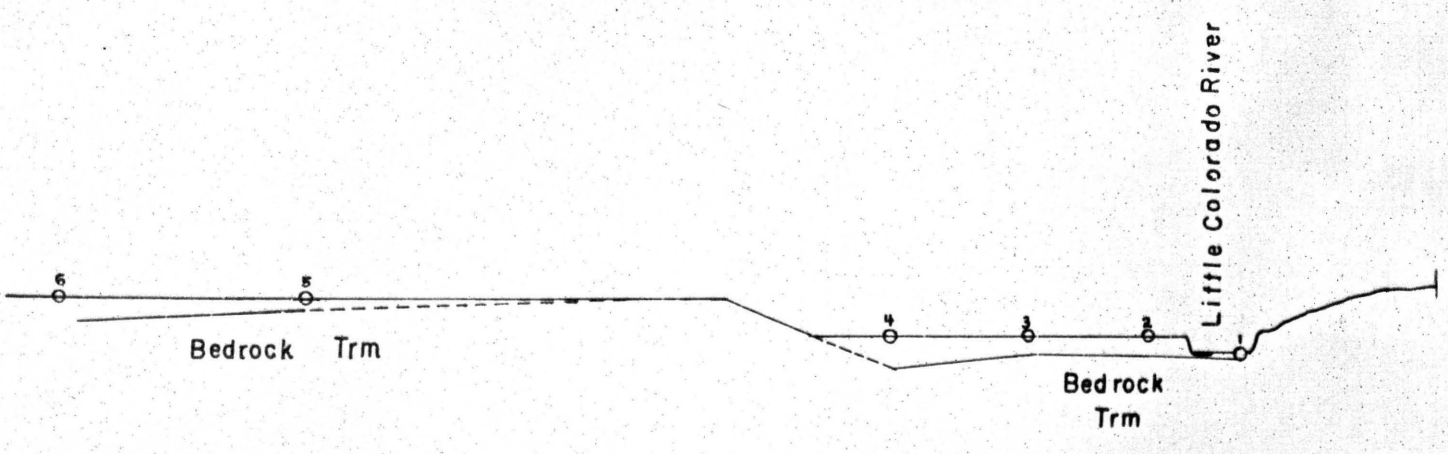


Figure 29

Cross section along axis with bed rock profile

Little Colorado River Dam Site Axis AB

1"= 200'

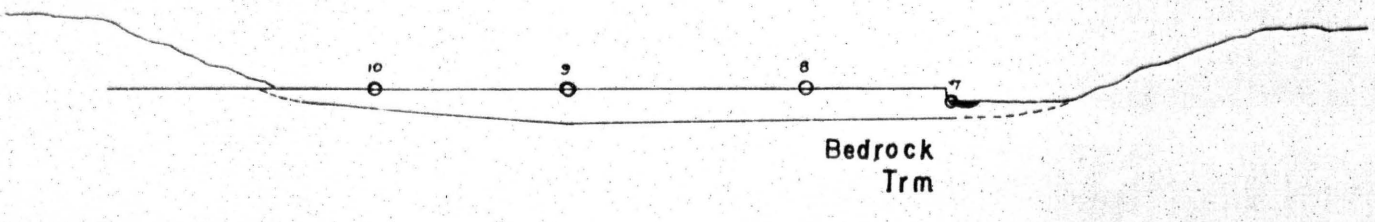


Figure 30

Cross section along axis with bed rock profile

Little Colorado River Dam Site Axis CD

1"=200'

Layers beneath centers of resistivity lines

Little Colorado River Dam Site

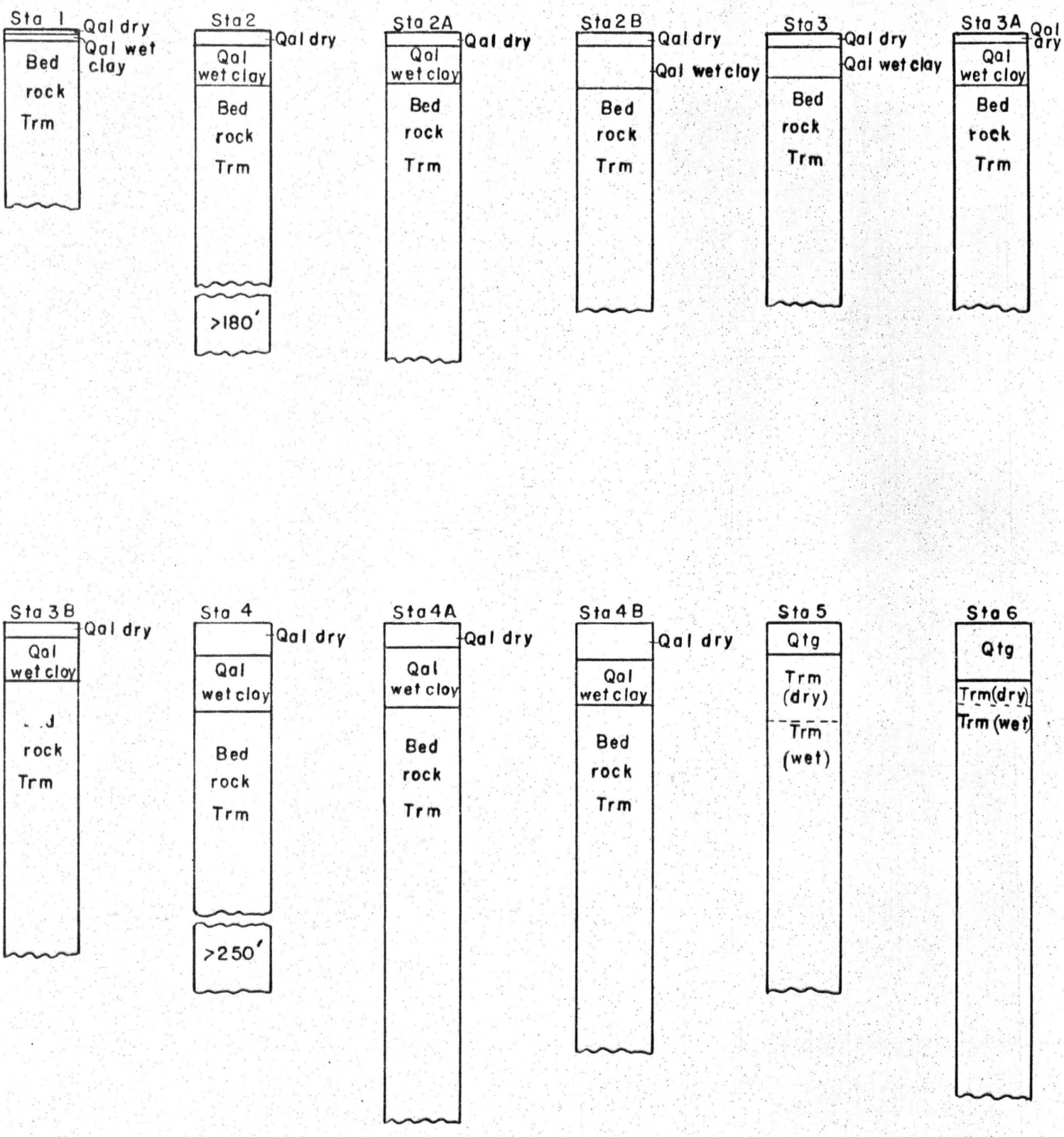


Figure 31

1" = 50'

Little Colorado River Dam Site

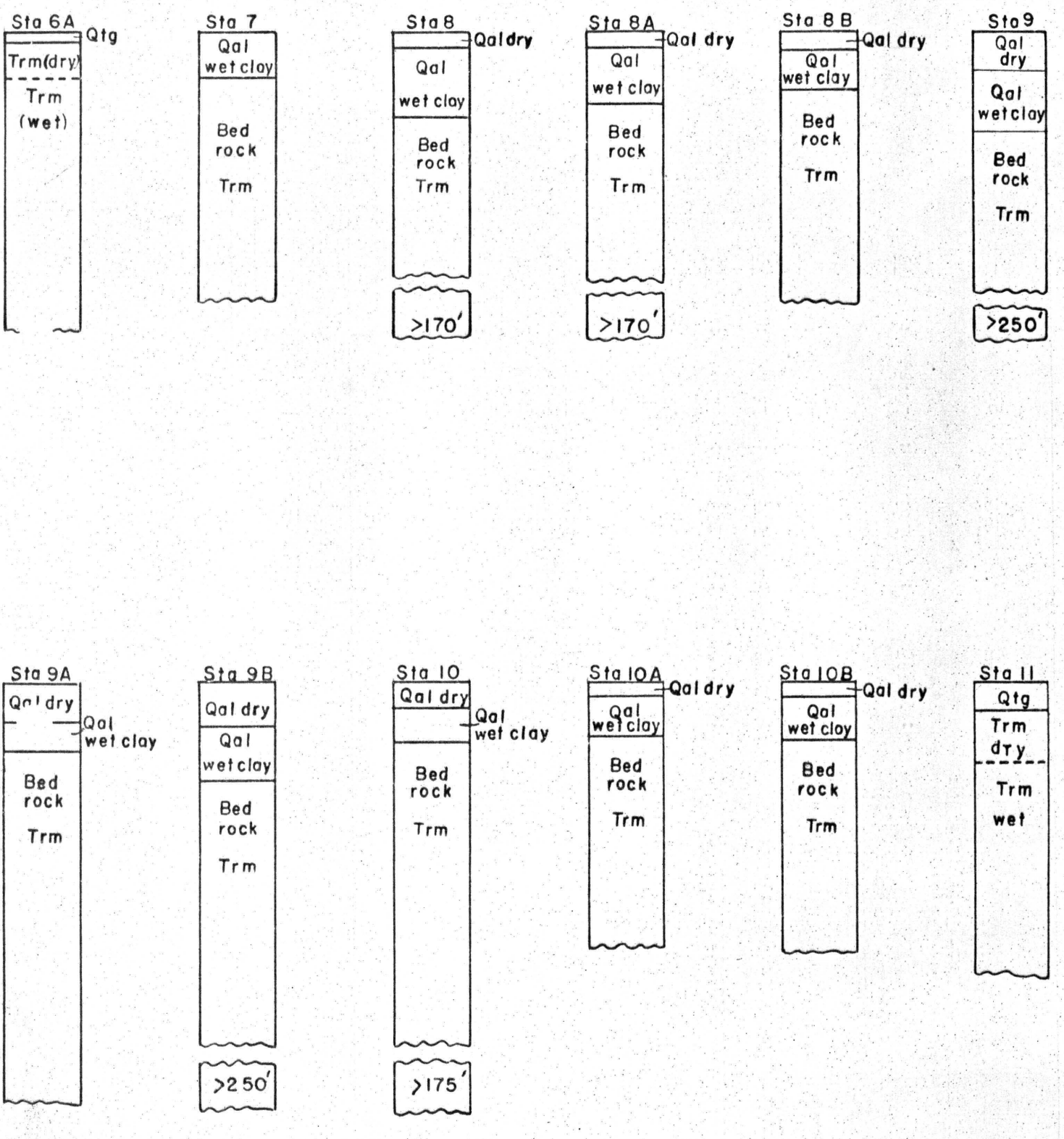


Figure 31 continued

Qualative thickness of Qtg and Trm

Little Colorado River Dam Site

Estimated cross section below resistivity line 12

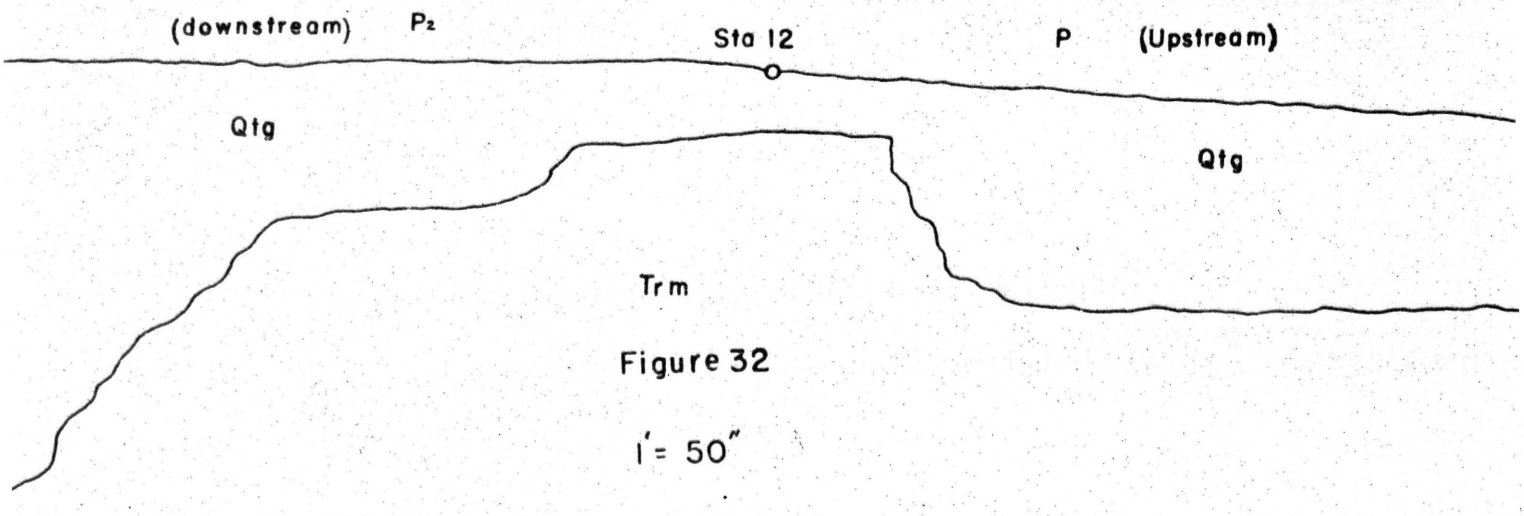


Figure 32

1' = 50'

Zuni River

Lower Zuni Dam Site

In all, sixteen resistivity lines were completed at this site; six on axis AB, four on axis CD, and six on axis EF. The position, direction, extent, and the maximum electrode separation of the lines are shown in Figure 33.

A summary of the interpretations from the apparent resistivity curves is given in Table 12, that is separated into groups of lines for each axis.

Cross sections along the three proposed axes are shown in Figures 34, 35, and 36. The bed rock profile was obtained from Table 12, Figure 33, and Plate 26 A (Mr. Piper's report).

The layers beneath the centers of the resistivity lines, obtained from the apparent resistivity curves, are estimated in Figure 37.

Considerable unevenness of the bed rock profile is noted in most of the curves and the major horizintal discontimuities will be mentioned that were found in the study of the apparent resistivity curves of this site. A consequent thickening of the overburden is indicated in every instance mentioned.

Line 1; P_1 70 feet to 120 feet interval; P_2 50 feet to 80 feet interval.

Line 2; P_1 70 feet to 120 feet interval;

Line 4; P_1 200 feet to 300 feet interval.

Line 5; P_1 and P_2 , 200 feet to 350 feet interval.

Line 6; P_1 and P_2 , 80 feet to 150 feet interval.

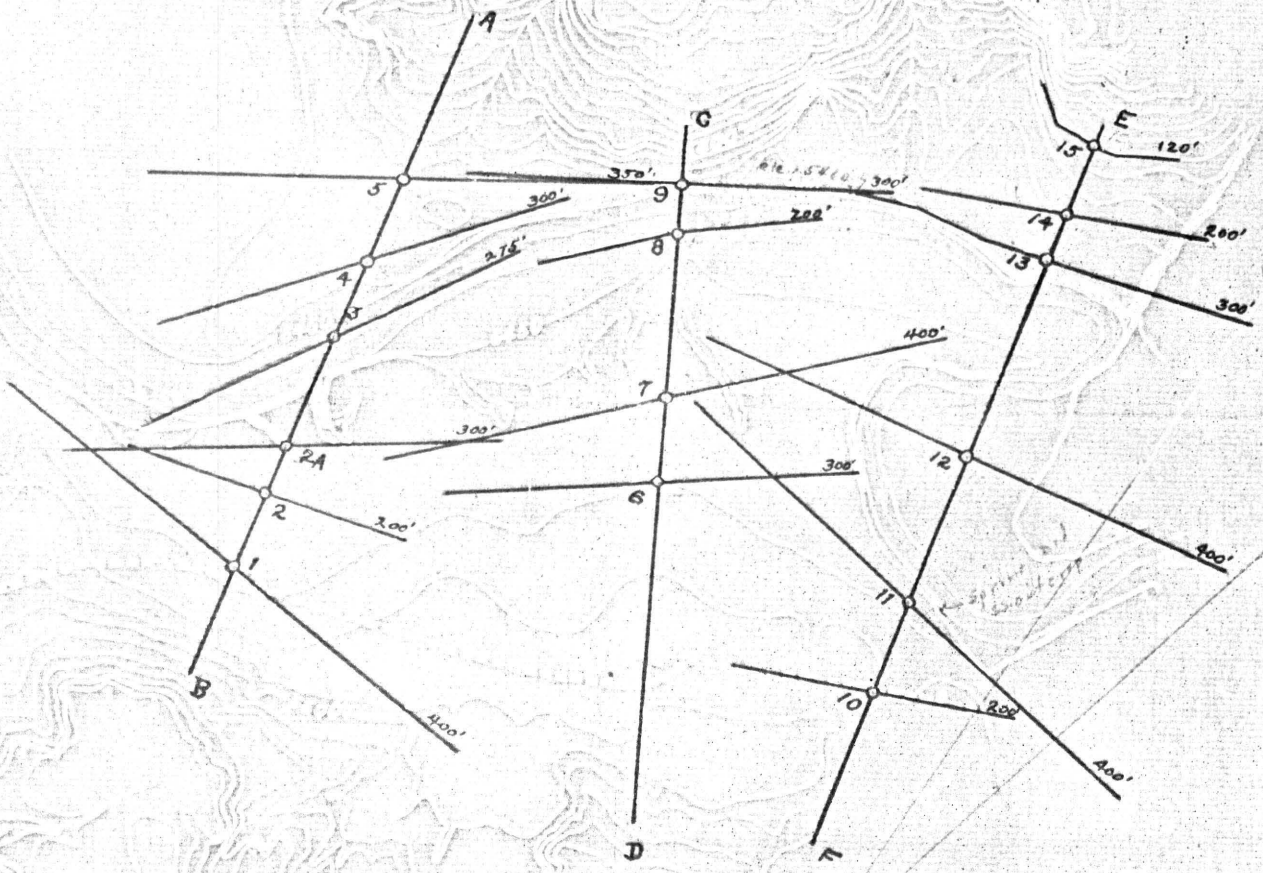
Line 7; P_1 , 60 feet to 100 feet, 160 feet to 200 feet, 325 feet to 400 feet intervals;

P_2 60 feet to 90 feet, 160 feet to 200 feet intervals.

Line 8; P_1 , 120 feet to 160 feet interval; P_2 90 feet to 160 feet interval.

Line 11; From the 30 feet interval to the 120 feet interval, there is a large general discontinuity of the bed rock formation indicating the probable existence of a nose like structure buried beneath the Qal. This is in part substantiated by an outcrop of Trm formation, or was considered to be such by cursory field examination, and a flowing spring in the vicinity of the penciled arrow, Figure 33, along the bend of the river near the center of line 11. This formation is not, however, shown by Mr. Piper on his map, Plate 26 A. Continuous bed rock is, therefore, at a depth considerably greater than the 6 feet given in Table 12, and a good estimate is not possible from the curve for this traverse. The thickness of the bed rock is probably as great as that of adjoining lines.

Line 13; P_R , 25 feet to 60 feet interval indicates a thickening of the Qal downstream from the center. This interpretation is substantiated by the uncovered bedrock formation that was observed in the wash about 200 feet upstream from the center of line 13. This bed rock formation appeared to be Trm with interbedded sandstone and shale members that had dips N-W downstream and S-E upstream. The amount of dip was not exactly determined. Also, the exposure of this formation is not shown by Mr. Piper on his map, Plate 26A. There is some indication, also, that the buried structure might have the similar nose-like shape of the exposed formations of the area.



Location, direction, extent, and maximum interval of resistivity lines

The Lower Zuni Dam Site

Figure 33

Table 12

Summary of interpretations of apparent resistivity curves

Lower Zuni Dam Site

Line or Station	Location	Elevation feet	Maximum Electrode Interval feet	Estimated depth of fill feet	Estimated thickness of bedrock feet
	Axis AB				
1.	20 feet streamward (on left bank) from center of road on axis	5470	400	6.5	> 200
2.	On left bank 130 feet streamward from center of road on axis	5464	200	9	> 175
2A.	On left bank 299.9 feet streamward from center of road on axis	5460	300	25	> 150
3.	On right bank 544 feet streamward from center of road on axis	5445	275	48	> 225
4.	On right bank 717 feet streamward from center of road on axis	5462	300	69	> 200
5.	On right bank 905.7 feet streamward from center of road on axis	5468	350	36	200
	Axis CD				
6.	On left bank, on axis 65 feet E 31° N (mag.) from B.M., 375 feet streamward	5470	300	17.5	> 250
7.	On left bank, on axis 65 feet E 31° N (mag.) from B.M., 550 feet streamward	5464	400	37	> 250
8.	On left bank, on axis, water's edge 65 feet E 31° N (mag.) from B.M., 890 feet streamward	5445	200	27	> 175
9.	On right bank, on axis 144.7 feet downstream from B.M. (elev. 5464.7)	5468	300	13	> 75
	Axis EF				
10.	Left bank 550 feet N.E. of B.M., 20 feet S.E. of road on axis	5480	200	4.5	100
11.	Left bank, on axis, 195 feet from center of line 10	5467	400	6	- -*
12.	Left bank, " " , 520 " " " " " " "	5444	400	69	250
13.	Right bank, " " , 143 " " Trs outcrop streamward	5472	300	48*	100
14.	Right bank, " " , 30 " " " " streamward	5482	200	15.5	> 100
15.	Right bank, on " , 120 " up contour from Trs outcrop	5510	120	27.5	> 75

* See text

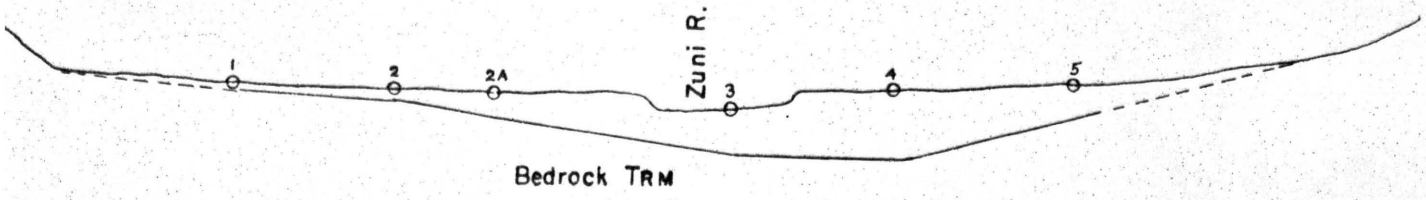


Figure 34

Cross section along axis $\overset{AB}{\wedge}$ with bedrock profile

Lower Zuni River Dam Site

1"= 200'

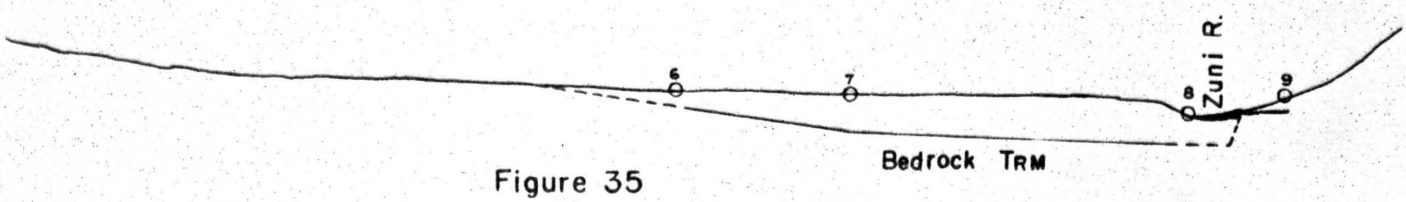


Figure 35

Cross section along axis $\overset{CD}{\wedge}$ with bedrock profile

Lower Zuni River Dam Site

1"= 200'

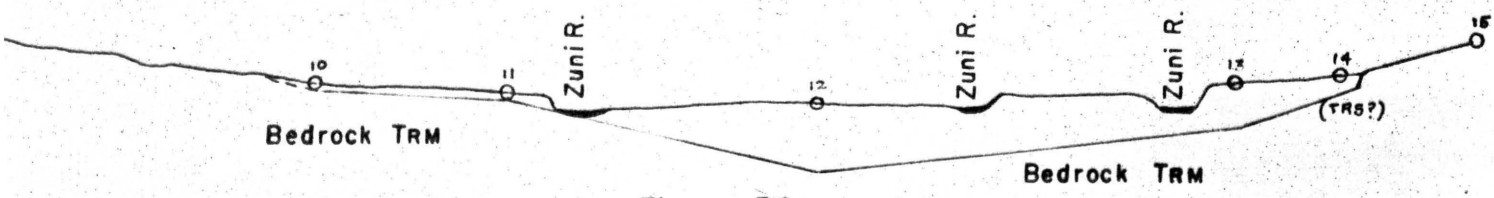


Figure 36

Cross section along axis $\overset{EF}{\wedge}$ with bedrock profile

Lower Zuni River Dam Site

1"= 200'

Layers beneath centers of resistivity lines

Lower Zuni River Dam Site

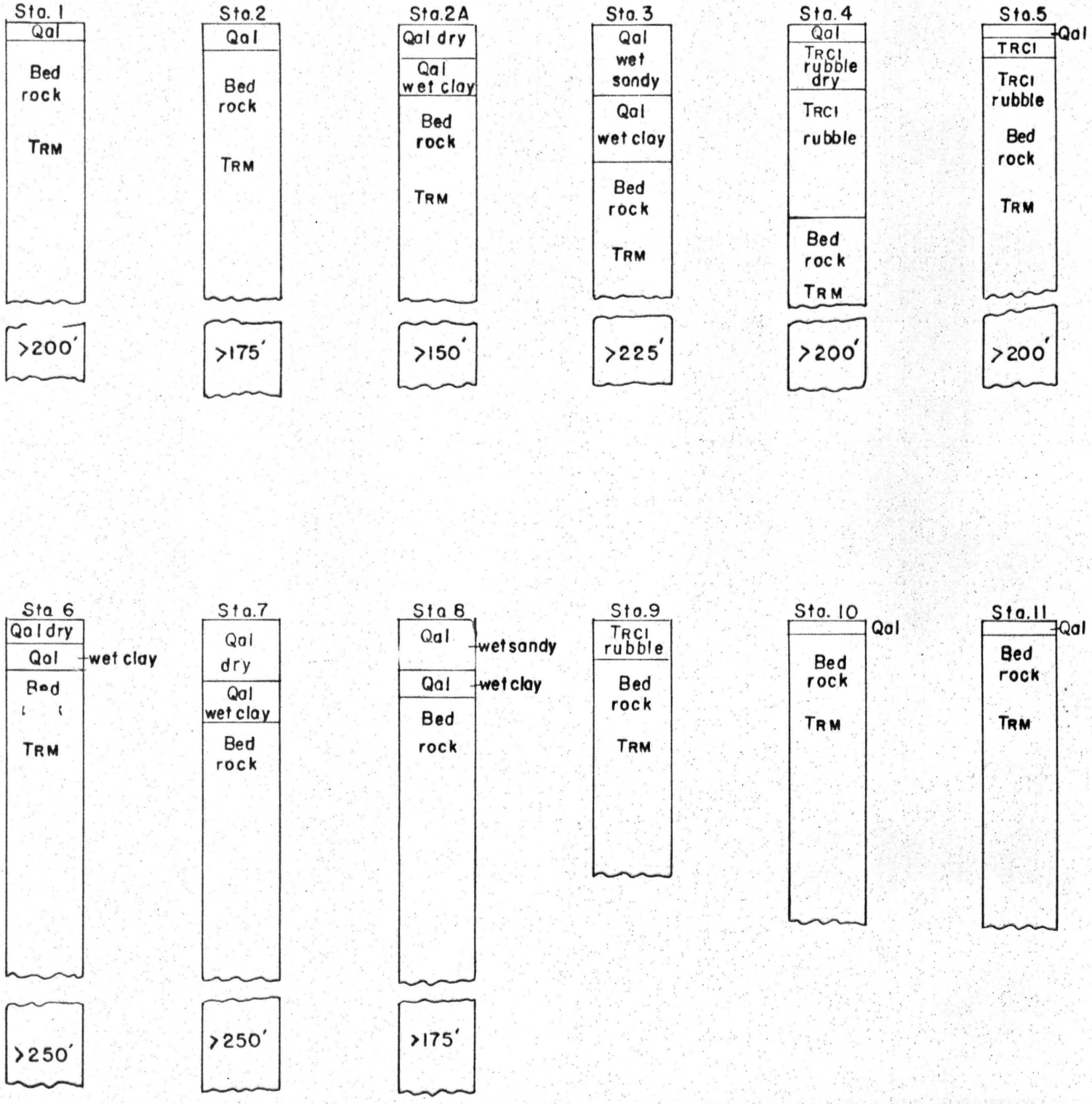


Figure 37
1" = 50'

Figure 37 continued

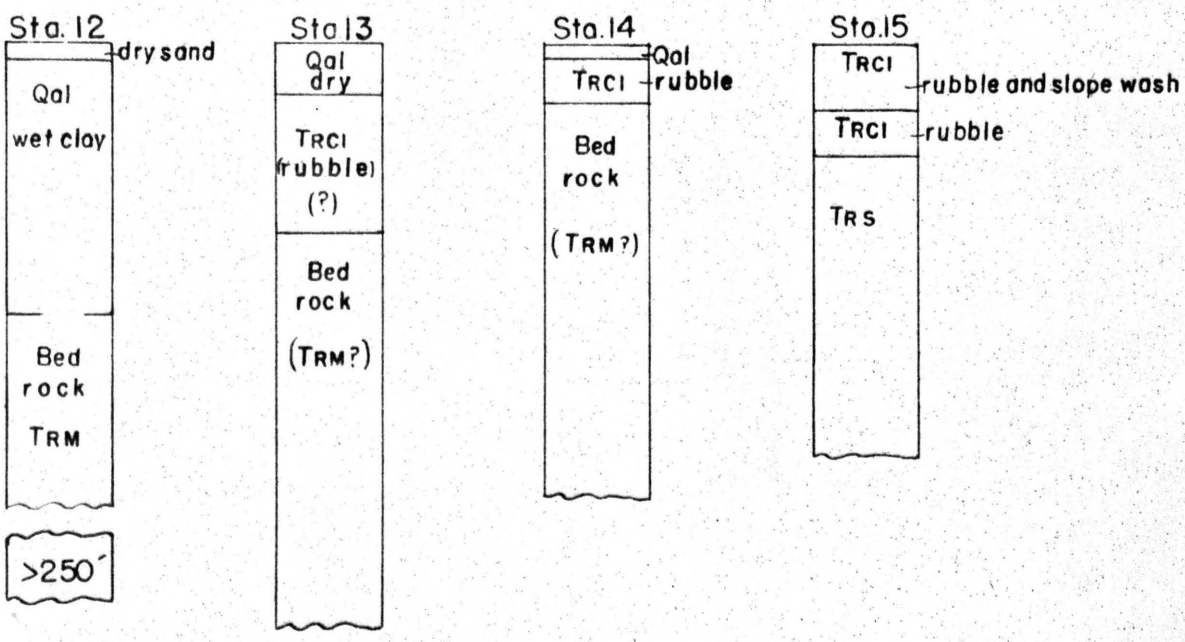


Figure 37 continued

Little Colorado River

Greer Dam Site

The ten resistivity lines for this site are shown in Figure 38, from which the position, direction, extent and the maximum electrode separation of the lines may be determined.

The interpretations of the apparent resistivity curves are summarized in Table 13. With the use of Figure 38, Table 13, and Plate 28 of Mr. Piper's report, Figure 39 was constructed which shows a profile of the bed rock in a cross section along the proposed axis. Comparative estimates for toe and heel depths of overburden will be found in Table 13 for positions at a distance of 150 feet from the axis. Line 4, which was centered on the opposite bank from the outcrop spur near the first "O" in Colorado (Plate 28, Mr. Piper's Report) about 270 feet upstream from the axis, is indicated on Figure 39 as a possible condition that may exist beneath the river bed along the axis. Thus, the Moenkopi formation either plunges valleyward and rises rapidly to a point beneath Line 1, or has been eroded to a greater depth below the present stream bed.

Taken as a whole, the bed rock profile is generally flat at this site. The greatest variation is indicated beneath Line 2 where the thickness of overburden may increase or decrease as much as several feet in places, Line 2B showing a particular instance. Unevenness of a lesser degree is an indicated condition beneath Line 1.

The probable formations beneath the traverses have been estimated from the curves, and are shown on Figure 40.

Location, direction, extent, and maximum interval of resistivity lines

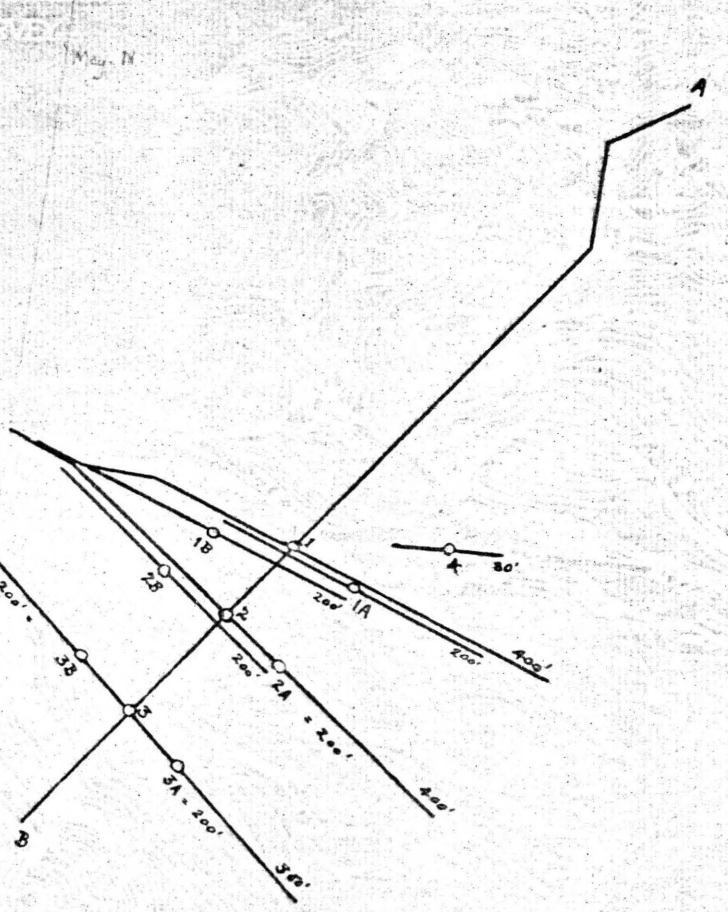


Figure 38

Table 13

Summary of interpretations of apparent resistivity curves

Greer Dam Site

Line or Station	Location	Elevation feet	Maximum electrode interval feet	Estimated ±10% Depth of fill feet	Estimated ±10% Thickness of bedrock feet
1.	Left bank, on axis, 52.4 feet from stream toward B.M.(elev. 5446)	5394	400	25	> 375
1A.	150 feet upstream from center of, and 15 feet ⊥ to Line 1, direction parallel	5394	200	24	> 175
1B.	150 feet downstream from center of, and 50 feet ⊥ to Line 1, direction parallel	5396	200	23	> 175
2.	Left bank, on axis, 251 feet from stream toward B.M. on left abutment	5392	400	36	> 350
2A.	150 feet upstream from center of, and on Line 2	5393	200	34	> 150
2B.	150 feet downstream from center of, and 25 feet ⊥ to Line 2, direction parallel	5394	200	43	> 150
3.	Left bank, on axis, 531 feet from stream toward B.M. on left abutment	5395	350	16.5	> 325
3A.	150 feet upstream from center of, and on Line 3	5394	200	15	> 175
3B.	150 feet downstream from center of, and on Line 3	5396	200	12.25	> 175
4.	Left bank, water's edge 42 feet from outcrop of Trm on right bank	5377	80	21	> 60

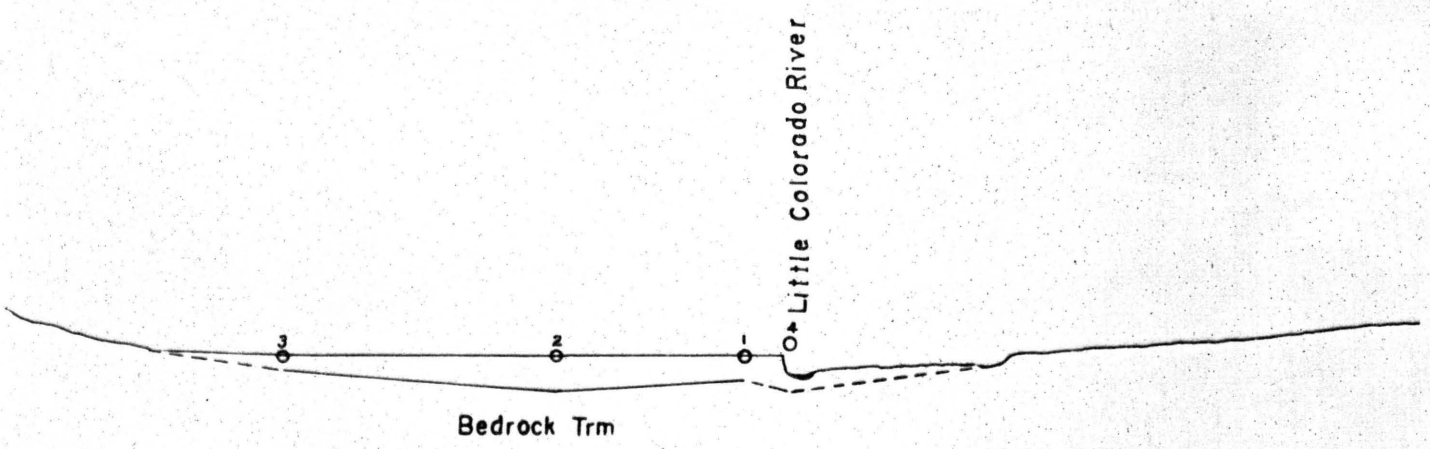


Figure 39

Cross section along axis with bed rock profile

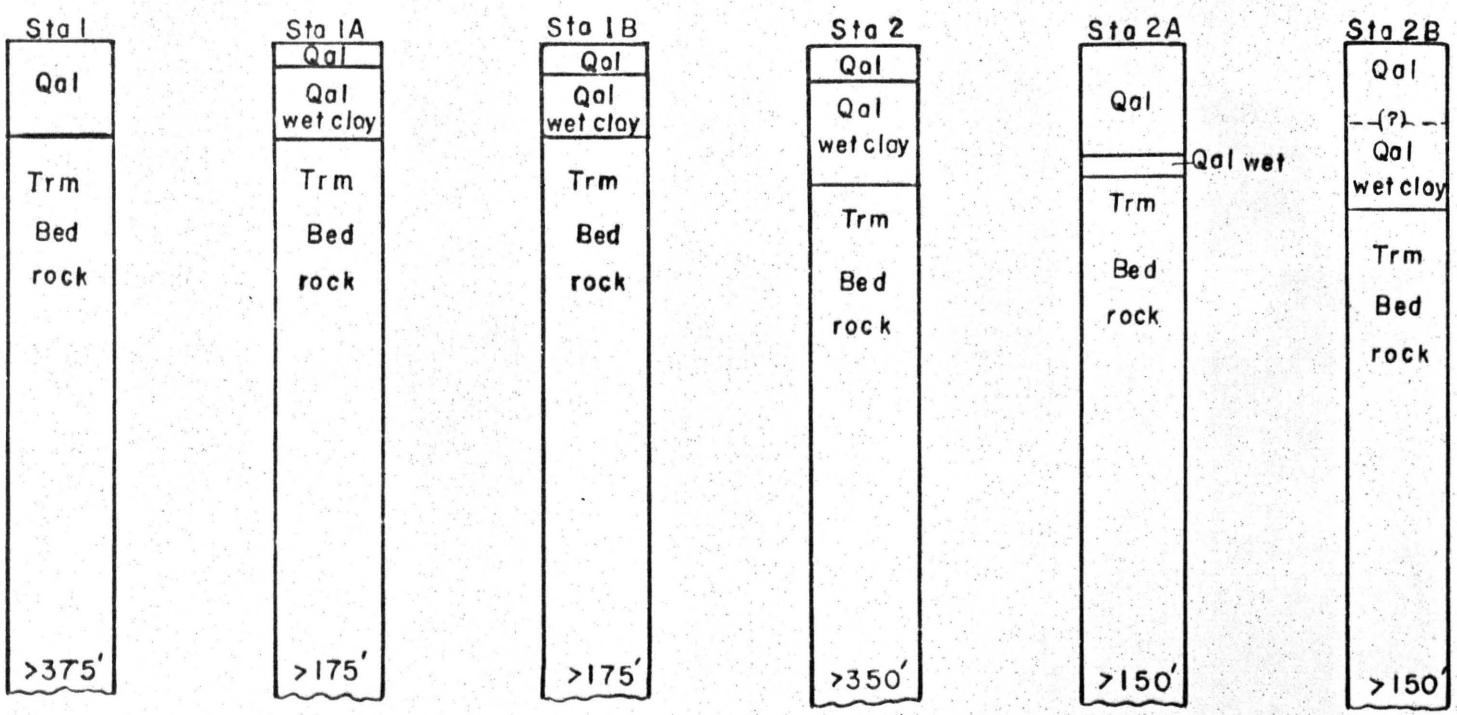
Greer Dam Site

Little Colorado River

1"=200'

Layers beneath resistivity line centers

Greer Dam Site



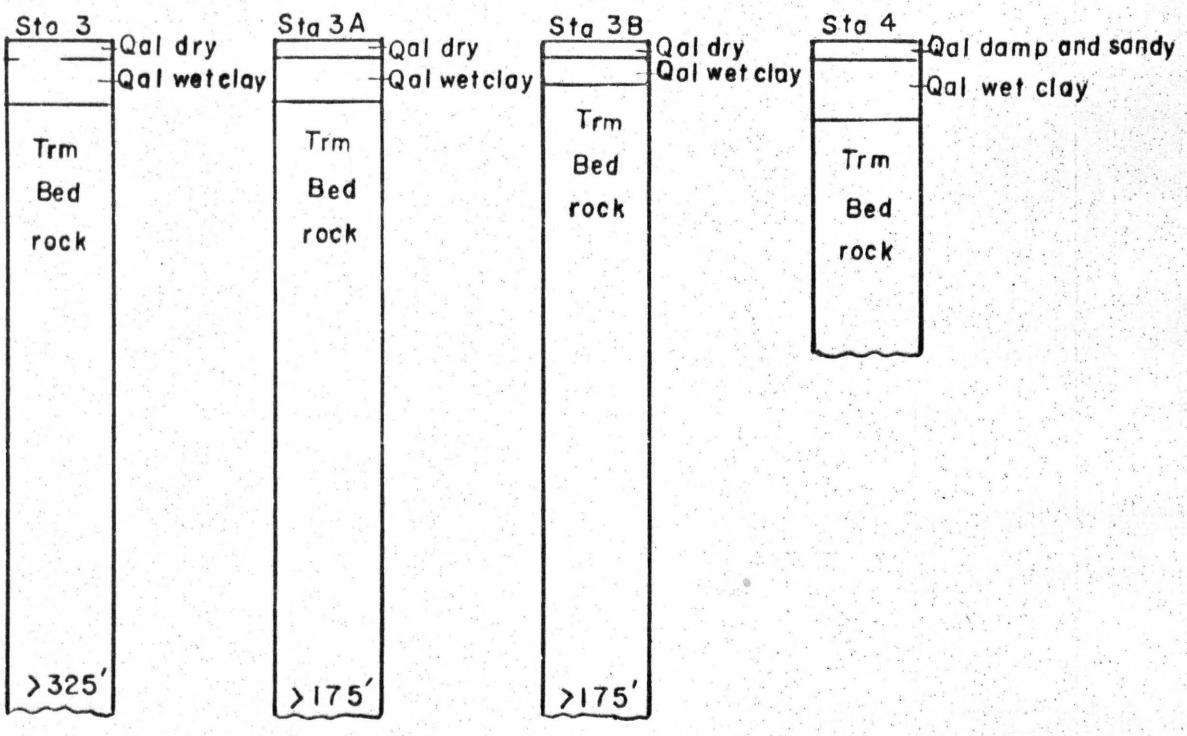


Figure 40

Little Colorado River

Forks Dam Site

The resistivity lines for this site, five in number, are shown in Figure 41 as to position, direction, extent, and maximum interval.

A summary of the interpretations of the apparent resistivity curves is given in Table 14. Figure 42 is a cross section that shows the bed rock profile beneath the land surface along the proposed axis and was prepared from Figure 41 and Table 14.

No positive determination of depth of overburden was obtainable from Line 1 or a retake, which was made the following day, using fresh batteries. The traverse was run over an extremely unfavorable Qal terrace deposit that was about 30 feet above the river level, and contained numerous pot hole washes, narrow ledges along the abutment wall, and was surfaced with deep, loose, dry sand. Also, as the line was very close to the abutment wall, results are probably altered somewhat from the usual horizontal layer conditions by which interpretations are made. However, there is some indication that bedrock may be found at a depth of 30 to 40 feet beneath the center of Line 1, but it probably is discontinuous horizontally both upstream and downstream and continuous bed rock probably will be deeper.

Line 3 shows an indicated depth to bedrock about 7 feet greater than Line 4 located 190 feet downstream; and the former may be a less reliable depth of fill determination by comparison with the depth from resistivity Line 2.

Dry tests on the top of the abutment gave very high values of resistance to the Coconino sandstone. No place could be found at any of the three downstream sites where a suitable wet test could be obtained on the rock as the walls were so steep and the alluvium always in contact with them so that vitiated results were obtained. However, the resistance of the bedrock from the curves is very high, almost equal to that of the usual value for dry sandstone, so it seems quite probable the layering encountered here is: wet quicksand Qal; Qal clay and weathered rock saturated with water containing more dissolved salts; and sandstone for all of the lines.

Other evidence supporting the interpretation that no shale is present beneath the streambed will be found in the report of the area by Harrell and Eckel [1/]. None of the well records of this report in the near vicinity of the three downstream sites contain a shale member in the Coconino sand stone, and the thickness is shown to have a minimum of 450 feet in the region.

1/ Harrell, Marshall A. and Eckel, Edwin B.- Groundwater resources of the Holbrook region, Arizona; Water Supply Paper 836-B, 1939. (Information supplied by Mr. Eckel.)

A formation test on the Coconino sandstone made subsequent to this report gave the following results for the 10, 20, and 30 foot intervals: 78,350; 96,594; and 114,112 ohm-cm. respectively. This test was made at the Holbrook Dam Site on the top of the right abutment near the axis.

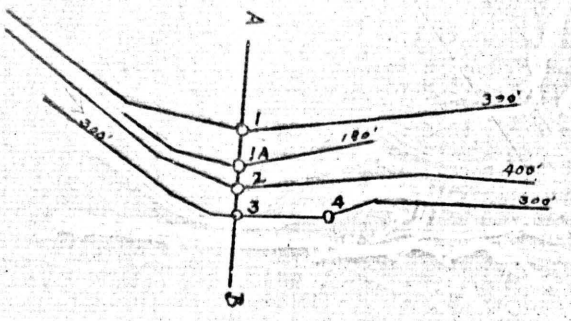


Figure 41

Table 14

Summary of interpretations of apparent resistivity curves

Forks Dam Site

Line or Station	Location	Elevation feet ±	Maximum Electrode Interval feet	Estimated ±10% Depth of fill feet	Estimated ±10% Thickness of bedrock feet
1	Left bank, on axis, 30' from left abutment	5177	390	*	
1A	Left bank, on axis, 97.8' from left abutment	5160	180	52	>100
2	Left bank, on axis, 151.2' from left abutment	5148	400	43	>350
3	Right bank, on axis, 187.2' from left abutment	5148	300	51*	>250
4	Right bank, 190' downstream from Line 3	5148	300	44	>250

* see text

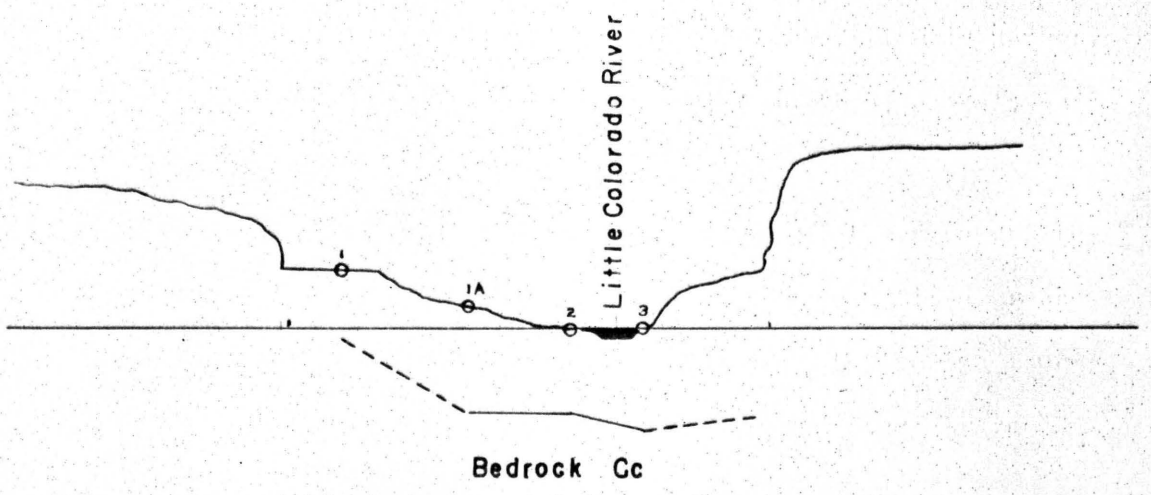


Figure 42

Cross section along axis with bedrock profile

Forks Dam Site

1"= 100'

Little Colorado River

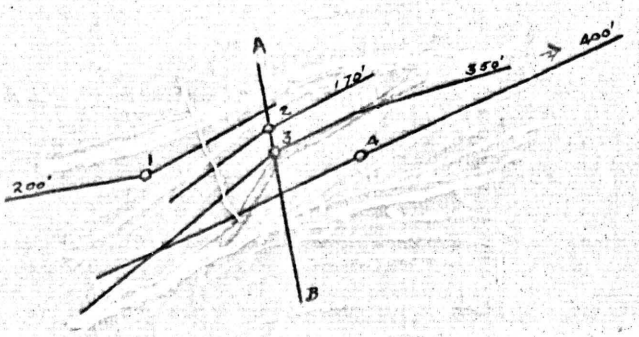
Woodruff Dam Site

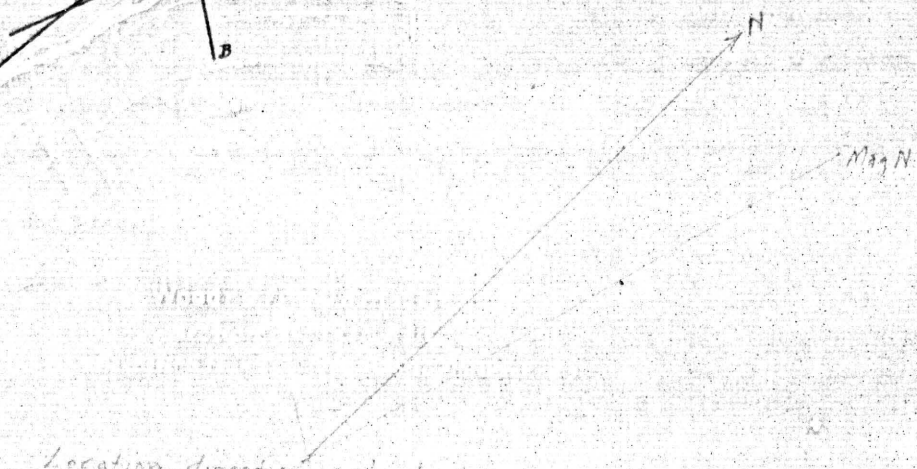
It was conveniently possible to locate but two of the four resistivity lines on the proposed axis of this site; the quicksand was rather treacherous and a bend in the river made it necessary to move downstream for the long line No. 4. The position, direction, extent and maximum interval of the lines is shown in Figure 43.

The interpretations of the apparent resistivity curves are summarized in Table 15. Figure 44 shows the depth of overburden above the bed rock along the proposed axis, and was prepared from Table 15 and Figure 43. The result from Line 4 is indicated as located on the axis where the traverse crosses, thus the dashed line.

The curves indicate that the surface contour of the bedrock is quite uniform in depth both up and down stream from the axis. The present water course along the river bed is somewhat changed from that when the map was made, and is sketched in pencil on Figure 43.

The layering at this site is interpreted to be the same as the Forks site upstream; wet quicksand Qal, Qal clay and weathered rock saturated with more concentrated salt water, and sandstone.





Location, direction, extent, and maximum interval of resistivity lines.

Figure 43

Table 15

Summary of interpretations of apparent resistivity curves

Woodruff Dam Site

Line or Station	Location	Elevation feet ±	Maximum Electrode Interval feet	Estimated ±10% Depth of fill feet	Estimated ±10% Thickness of bedrock feet
1	Left bank, 525' upstream from B.M. (5109) 65' from left abutment	5131	200	19	>175
2	Left bank, on axis, 245' upstream from B.M. (5109), high water's edge, 58' from abutment	5105	170	20	>150
3	Left bank, water's edge, along axis 49' from Line 2	5103	350	44	>200
4	Right bank, 100' along axis from Line 2, thence 175' ⊥ downstream from axis	5104	400	46	>250

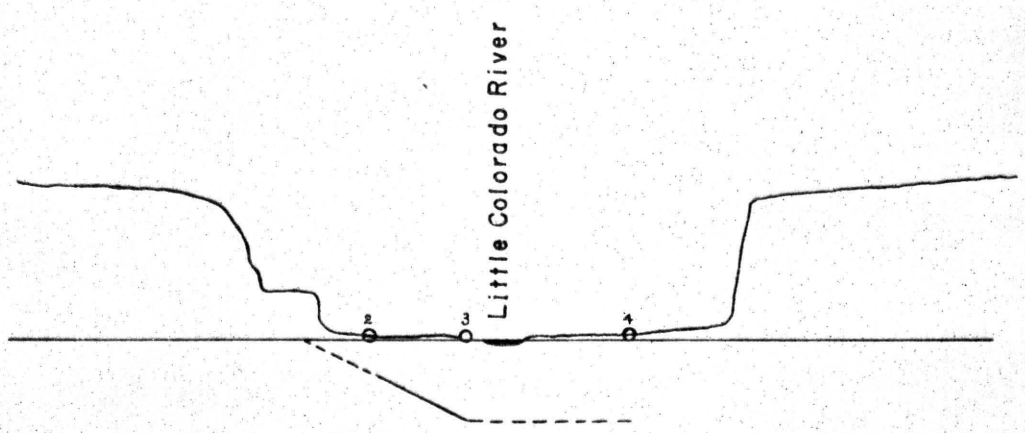


Figure 44

Cross section along axis with bedrock profile

Woodruff Dam Site

1"= 100'

Little Colorado River

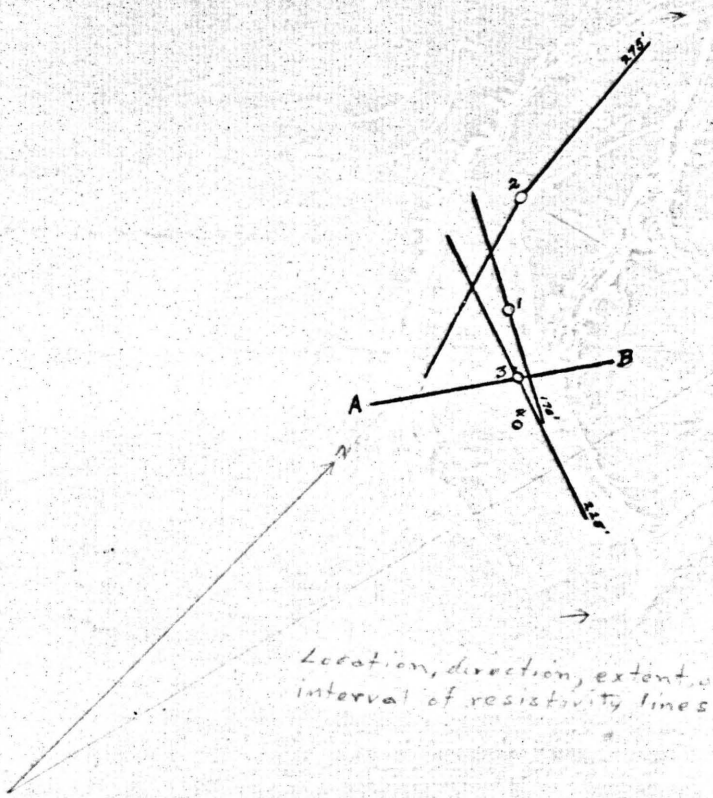
Holbrook Dam Site

Three resistivity lines were completed at this site, located, as shown in Figure 45, with but one on the proposed axis. A fourth was attempted with the center on the right bank of the stream above the axis, but was abandoned as it was over quicksand that exuded water in sufficient quantity to change the readings of subsequent intervals so that consistent apparent resistivity values could not be obtained. The direction, extent, and maximum interval of the lines are also shown on Figure 45.

The interpretations of the resistivity curves are summarized in Table 16. A cross section along the proposed axis is given in Figure 46.

The layering at this site is interpreted to be the same as that of the two sites immediately upstream. Qal wet quicksand, Qal wet clay, and sandstone.

Some debris, possibly broken sandstone, may be present beneath Line 2 overlying the continuous bed rock and extends toward the right abutment.



Location, direction, extent, and maximum interval of resistivity lines.

Figure 45

Table 16

Summary of interpretations of apparent resistivity curves

Holbrook Dam Site

Line or Station	Location	Elevation feet ±	Maximum Electrode Interval feet	Estimated ±10% Depth of fill feet	Estimated ±10% Thickness of bedrock feet
1	Right bank, 61' along axis from right abutment, thence 142' W 14° N mag. downstream	5095	170	74	>100
2	Right bank, 210' from base of right abutment on Line E 30° N (mag.) from B.M. (5201)	5095	275	104	>150
3	Right bank, 82.5' from base of right abutment along axis	5094	225	87	>150
4	Right bank, 90' from line 3, 10' from edge of stream on line E 32° S (mag.)	5093	abandoned		

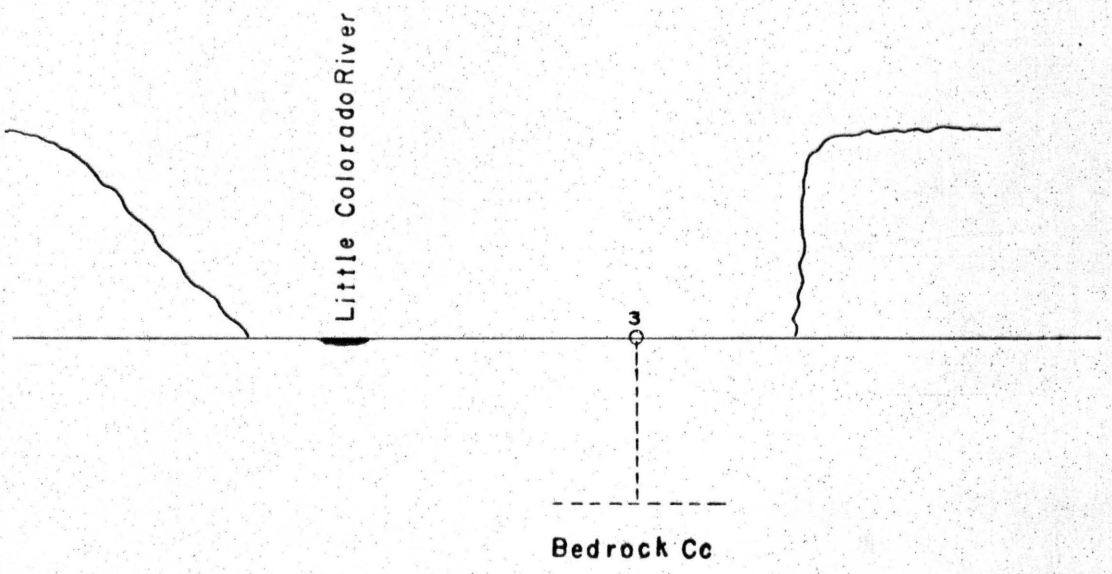


Figure 46

Cross section along axis with bed rock profile

Holbrook Dam Site

1"= 100'