

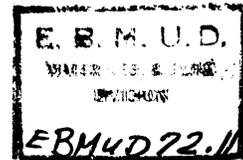
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EAST BAY MUNICIPAL UTILITY DISTRICT
MOKELUMNE RIVER DEVELOPMENT

CAMANCHE DAM AND RESERVOIR
GEOLOGIC REPORT

MARCH 1961

PREPARED BY
BECHTEL CORPORATION



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CAMANCHE DAM AND RESERVOIR GEOLOGIC REPORT

I - INTRODUCTION

Objectives

The objective of this investigation was to evaluate the geologic conditions at the Camanche Dam site which would affect the design and construction of the proposed engineering features. Possible reservoir seepage losses and the permeability of foundation materials were to be given careful consideration. A mapping program was to be initiated and be in sufficient detail to provide data on the location, continuity, and physical characteristics of the various rock units. Plans included the preparation of a lithofacies map which would delineate the various rock types with special emphasis to be placed on the location and extent of the more permeable zones. However, this method of presentation was not practical due to the highly lenticular nature of the deposits.

A drilling program was designed to furnish subsurface data on the location and extent of the various rock units. Core samples were to be evaluated by inspection and by determination of the permeability and strength of the rock.

Field permeability determinations were to be made by the usual water test methods and also by detailed pump tests. Investigation

of the possible source of riprap and evaluation of several sources of concrete aggregate were also part of the objectives of this study.

Scope of Work

The present investigation program included extensive diamond core drilling, sampling, and testing; detailed field mapping; numerous exploratory dozer cuts and pits; power auger holes, dragline excavations; and exploration and water testing of pre-existing shafts and adits. In all, a total of 26 four-inch diamond core holes were drilled with a total footage of 2260 feet and an overall core recovery of 92 percent for the intervals cored. A lesser amount of NX drilling, churn drilling, and rock-bit drilling were also accomplished. These were primarily for special purposes such as penetrating river gravel overburden or drilling piezometer holes. The power auger was used to determine the thickness and composition of the loosely consolidated alluvium which is only partially amenable to coring. The exploration program is summarized in Table I.

TABLE I

EXPLORATORY DRILL HOLES

Method	No. of Holes	Footage Drilled (ft)	Remarks
Core Drilling - 4" dia.	26 ⁽¹⁾	2259.8	92.3% core recovery
Core Drilling NX - Quarry Sites	6	490.7	100% core recovery
Rock-Bit Drilling	9	815 ⁽²⁾	Cutting Samples
Churn Drilling (river section)	4	92	Cutting Samples
Auger ⁽³⁾ - 12 inch	16	610.5	Jar Samples
Denison Sampler	3	177.1	19 Samples

(1) Includes 68.8 feet of drill hole TT 3-9.

(2) Includes 120 feet of TT 3-9.

(3) Does not include holes drilled exclusively for embankment materials investigation.

The field testing pertained primarily to rock permeabilities.

Pressure and/or atmospheric water tests were made on selected intervals of the core holes and Denison and other core samples taken for laboratory testing. One shaft and one adit-shaft combination along with specially drilled wells in the Mehrten formation were also water-tested for permeability data. The locations of the drill holes are shown on Plate I.

In conjunction with the detailed mapping of the dam site, dozer cuts were made along the alignment of the proposed structures to supplement natural exposures of foundation materials. These, together with the core holes, provided geologic data of the critical area. Within the reservoir area, the outcrops of the Mehrten formation were mapped in detail, and the Valley Springs and older formations were covered by field reconnaissance.

The current investigation covers the period from August 1960 to February 1961.

Description

Camanche Dam site is on the Mokelumne River in San Joaquin County, California approximately 30 miles upstream, north and east of Stockton, and 11 miles downstream from the existing Pardee Dam. The dam will be comprised of a main earthfill dam about 2500 feet long and four miles of earth dikes to form a reservoir extending to the base of Pardee Dam. The ^{431,550}~~430,000~~ acre-foot reservoir will provide an increased amount of water to be stored in Pardee Reservoir for diversion to the District's aqueduct system. Topographically it is situated among low sedimentary hills of the outermost Sierran foothills. The river elevation at the proposed axis is about 100 feet above sea level. A detailed description of the project may be found in Chapter I of the "Camanche Dam Basic Design Report".

Previous Investigations

The geology and hydrology of the area was studied by the United States Geological Survey and reported in Water Supply Papers 619 and 780. Preliminary investigations of the site were made by both the Sacramento District of the Corps of Engineers and the California Department of Water Resources.

Exploration of the site was first undertaken by the East Bay Municipal Utility District in 1952. The results of this study are reported in "EBMUD Ultimate Mokelumne River Development, Preliminary Design of Proposed Camanche Dam, Spillway and Appurtenances", March, 1953.

The area was mapped by reconnaissance methods in 1959 during Bechtel Corporation's evaluation of several proposed sites along the Mokelumne River for East Bay Municipal Utility District.

II - CONCLUSIONS

1. The completed geologic studies and explorations verify that the geologic conditions are suitable for the construction of the proposed dam and appurtenant works.

2. Field permeability tests indicate that the permeability of a pertinent section of the Mehrten formation on the left abutment is about 2,000 feet per year. Tests at five locations on the right abutment indicate a permeability range of 30 to 375 feet per year.

3. Adequate quantities of suitable riprap are available within eleven road miles of the dam site. The riprap must be quarried.

4. Suitable concrete aggregates are available within three miles of the dam site if Type II, low alkali cement is used.

III - GENERAL GEOLOGY

Crystalline Rocks. The oldest rocks in the reservoir area are the pre-Cretaceous slates, schists, phyllites and greenstones which are part of the Sierra-Nevada basement complex. These rocks occur in the eastern or upstream portion of the reservoir area. They provide the most likely source of riprap material for the proposed dam.

Ione Formation. The Ione formation of Eocene age is the oldest of the sedimentary formations in the reservoir site. It is composed of quartzose sand and conglomerate and clay. This unit is confined to the eastern portion of the reservoir area where it dips gently westward. The contact between the Ione formation and the underlying pre-Cretaceous rocks is a distinct angular unconformity.

Valley Springs Formation. Unconformably overlying the Ione formation is the Valley Springs formation of Miocene age. The Valley Springs formation, shown on Plate II as Tv, is comprised of tuffs, sandstones, claystones and occasional conglomerates. This formation is exposed in the reservoir area to within a mile of the dam site and was encountered in a number of the drill holes along the axis line. The Valley Springs formation is typically whitish in appearance and high in quartz, volcanic glass, pumice, and biotite fragments. Sandstones in this formation are fine-to coarse-grained and are generally well cemented

with a clay binder. The ratio of clay to sand varies from a sandy claystone to a clayey sandstone. The conglomerates form a small fraction of this formation and consist primarily of quartz and pre-Cretaceous rocks with occasional zones of large pumice fragments. The tuff members are of several types; the most apparent is a snow-white vitric tuff. Another widespread type of tuff is gray-green to yellow-green and is very fine-grained showing various degrees of alteration to clay. In the cases where the alteration is complete, claystone results with only faint relict texture remaining to indicate origin. Tuffaceous sandstone and conglomerate are also common.

Mehrten Formation. The Mehrten formation, indicated on Plate II by the symbols Tm and Tma, overlies the Valley Springs formation and is of Mio-Pliocene age. The Mehrten formation was deposited on an erosion surface similar to the present topography, although the drainage appears to have been more to the southwest. Channels cut to depths greater than 150 feet in the Valley Springs formation prior to deposition of the Mehrten have been found in the reservoir area.

The Mehrten formation varies in rock type from mudflow or agglomerate, to conglomerate, sandstone, siltstone, and claystone. The mudflows are typically hard and impervious and are composed of angular volcanic fragments. The fragments range in size from sand to boulder and are well cemented in a silty matrix. They were formed during times

of volcanic activity by torrential rains washing off slopes littered with loose volcanic ejecta and sluicing it into the drainage channels. The fluids formed by the mixture of soil, rock and water moved down the stream channels and spread out on the flat lands. The thickness of the beds and the size of transported blocks depend upon the viscosity and velocity of the flow. Mudflows containing blocks up to 2 feet in diameter are present in the dam site area interbedded with horizons whose grain size is not larger than small pebbles. Because the mudflows traveled down or intersected old drainage routes, occasional rock fragments other than volcanic are present. When the mudflows finally came to rest they were well graded and contained sufficient fines to form a natural cement. Thus upon lithification they became hard (resembling a poor grade concrete) and are commonly seen projecting as ribs on the canyon walls and/or capping the ridges. Mudflows were sufficiently numerous during certain intervals of deposition of the Mehrten formation to fill drainage channels 70 feet or greater in depth and overflow onto the flat surrounding land.

In general, the bedding in the Mehrten formation is too lenticular for satisfactory determination of its attitude by graphic means and its dip is too shallow and variable for accurate compass readings. Correlation of the relatively thin mudflow unit in the river section consequently was most useful and indicated the strike is N 20° W with a dip of about 1° S W.

The mudflows so characteristic of the Mehrten formation do not appear to be confined to any particular horizon. For example, on the Buena Vista Road, just east of the Amador-San Joaquin county line, the mudflows are in contact with the Valley Springs formation at elevation 200. Following up the same hill at less than 1500 feet away they also cap the ridge at elevation 320. In this particular area, three separate mudflows were mapped and several other noted. The materials between the flows are sandstones and conglomerates which make up the bulk of the Mehrten formation.

The Mehrten conglomerates are formed primarily of andesitic rock with a minor amount of re-worked Valley Springs and older formations. The rocks are generally of pebble-cobble size in a matrix of fine-to coarse-grained sandstone. The degree of cementation varies widely, some units form resistant ledges and others are very friable. The average conglomerate bed is gray to brown, moderately friable, locally well cemented and has a relatively low permeability. Correlation between conglomerate exposures in the Mehrten formation is difficult as they are highly lenticular.

The most widespread sediments in the Mehrten formation are the sandstones which comprise over 50% of the material. They also occur as lenticular bodies and may be seen grading into siltstones at one extreme and into conglomerates at the other. The typical sandstones

are composed of sub-rounded to sub-angular grains chiefly of andesitic origin, but with significant amounts of quartz and hornblende. Some of the basal beds consist primarily of re-worked Valley Springs material and are high in quartz and pumice fragments. The most typical sands are dark gray but have a bluish cast due to a very thin siliceous coating. These sands are river and flood-plain deposits. The coarse-grained, cross-bedded types represent the former, and the more continuous, fine-grained varieties represent the latter.

The siltstones and claystones of this formation are generally gray to dark brown and well cemented with thin to massive bedding.

With some of the sandstone and siltstone horizons, there are deposits of siliceous sinter precipitated along paths of water percolation. These siliceous deposits occur most often as fine streaks striking at random through the beds in the form of thin horizontal fracture fillings, but occasionally they occur as definite beds up to 6 inches thick. There is a tendency for the rock to be weakened by these porous deposits.

The following two tables are typical geologic sections of portions of the Mehrten formation exposed in each abutment.

TABLE II

GEOLOGIC SECTION OF THE MEHRTEN FORMATION
LEFT ABUTMENT

Top Elevation: 267 feet

<u>Thickness</u>	<u>Description</u>
71 ft.	<u>Mudflow</u> , with boulders, up to 2 feet in diameter, poorly sorted silt to coarse sand matrix, hard, impervious.
21 ft.	<u>Sandstone</u> , dark brown, moderately well cemented, well sorted, fine-to-medium-grained.
2 ft.	<u>Conglomerate</u> , brown, well cemented volcanic fragments.
6.5 ft.	<u>Siltstone</u> , brown, well cemented.
1.5 ft.	<u>Conglomerate</u> , brown, well cemented volcanic fragments.
1.9 ft.	<u>Siltstone</u> , brown, well cemented, hard.
1.1 ft.	<u>Sandstone</u> , blue, medium-grained, well sorted, poorly cemented.
3 ft.	<u>Claystone</u> , gray, hard, silty.
2 ft.	<u>Sandstone</u> , brown, well graded, silty.
5.2 ft.	<u>Siltstone</u> , brown, well cemented, locally very fine-grained sandstone.
5.3 ft.	<u>Sandstone</u> , brown, fine-grained, silty, well cemented.
30.5 ft.	<u>Sandstone</u> , brown, fine-grained, silty with thin claystone beds and very small interconnected root casts.
2.5 ft.	<u>Siltstone</u> , brown, hard, well cemented, trace of clay.
4 ft.	<u>Sandstone</u> , brown, fine-grained, poorly cemented.
2.7 ft.	<u>Claystone</u> , brown, hard, brittle, locally silty.

TABLE II (continued)

<u>Thickness</u>	<u>Description</u>
1.8 ft.	<u>Sandstone</u> , brown, fine-grained, poorly cemented.
6.2 ft.	<u>Siltstone</u> , brown, moderately well to poorly cemented locally fine, sandy.
5.5 ft.	<u>Sandstone</u> , brown, fine-to medium-grained, moderately well to locally poorly cemented.
0.9 ft.	<u>Claystone</u> , brown, hard, brittle, silty.
12.7 ft.	<u>Sandstone</u> , brown, locally fine-grained to medium-grained, silty, poorly cemented, locally clayey.
4 ft.	Covered.
19 ft.	<u>Siltstone</u> , light brown to gray, locally clayey and locally poorly cemented sandstone.
10 ft.	<u>Claystone</u> , light gray, silty, sandy at base, hard, occasional zones of brecciation and rehealed.
13.5 ft.	<u>Sandstone</u> , fine-to medium-grained, thin siltstone and claystone beds, small pumice fragments, moderately well cemented but poorly cemented in siltstone zones. Medium-to coarse-grained at base.
6.5 ft.	<u>Claystone</u> , light brown, silty, siliceous material in fractures.
4.5 ft.	<u>Sandstone</u> , dark gray, tuffaceous, fine-to medium-grained, moderately well cemented.

Bottom Elevation: 22 feet

TABLE III

GEOLOGIC SECTION OF THE MEHRTEN FORMATION
RIGHT ABUTMENT

Top Elevation: 313 feet

<u>Thickness</u>	<u>Description</u>
204 9 ft.	<u>Mudflow</u> , with boulders and blocks 4 feet in diameter and in a poorly sorted pebble-sized conglomerate matrix.
302 2 ft.	Covered.
281 15 ft.	<u>Sandstone</u> , varying from bedded silty fine-grained sandstone to sand-size mudflow units to friable medium-grained gray sandstone. Thin interval is poorly exposed.
9.5 ft.	<u>Conglomerate</u> , andesitic cobbles and pebbles, in a poorly sorted predominately coarse-grained sandstone matrix.
276 1.5 ft.	<u>Siltstone</u> , brown clayey and firm.
13 ft.	<u>Sandstone</u> , medium-grained. Generally poorly sorted but with local coarser zones. "Case hardened", but only moderately firm to moderately friable beneath.
248 15 ft.	<u>Sandstone</u> , friable, laminated to cross-bedded. Predominately coarse-to medium-grained with local thin siltstone beds and conglomerate pockets.
0.5 ft.	<u>Claystone</u> , brown, brittle.
236 11.5 ft.	<u>Sandstone</u> , medium-to fine-grained, locally case hardened but generally moderately friable. Siliceous sinter zone to 1 inch thick present.
14.5 ft.	<u>Conglomerate</u> , pebble-to cobble-size, andesitic material, poorly cemented. Matrix is bluish, medium-to coarse-grained sandstone.
206 16 ft.	<u>Sandstone</u> , medium-to coarse-grained, brown, moderately well cemented to friable. Local siltstone and conglomerate lenses.

El. 115
 - 12
 103

TABLE III (continued)

<u>Thickness</u>	<u>Description</u>
193 13 ft.	<u>Mudflow</u> , brown, granular size with occasional cobbles, angular blocks and well cemented. Occasional interbed of well cemented silty sandstone.
173 20.5 ft.	<u>Sandstone-Siltstone</u> , interbedded and intergraded fine-to medium-grained sandstones and siltstones. Brown, moderately-to poorly-cemented with occasional isolated small solution cavities. ?
171 1.5 ft.	<u>Clay</u> , soft, yellow. ? <i>unconformity?</i> <i>Valley Springs?</i>
151 20 ft.	<u>Sandstone-Siltstone</u> , interbedded, some minor claystones, moderately-to poorly-cemented and with isolated small solution cavities. ?
144 7.5 ft.	<u>Claystones</u> , brittle, brown, thinly bedded with trace of cross bedding. Occasional silty zones.
133 11 ft.	<u>Sandstone</u> , silty, medium-to fine-grained. Dark Brown and moderately well cemented.
127 6 ft.	<u>Claystone</u> , light brown to white with interbeds of siltstone, well cemented, brecciated and rehealed.
111 16.5 ft.	<u>Sandstone</u> , fine-grained silty, brown to blue-black in color. Generally firm with zones of medium-to coarse-grained poorly cemented sandstone in the lower 7 feet. ?
109 1.5 ft.	<u>Clay</u> , yellow, soft.
102 7 ft.	<i>Topst core?</i> <u>Sandstone-Siltstone</u> , brown to blue-black clayey siltstones grading to sandstones. Vein of siliceous sinter.
92 10 ft.	<u>Sandstone</u> , medium-grained, blue-black, well sorted, poorly cemented, slightly pumiceous.
72 19.5 ft.	<u>Claystone</u> , white to buff in color, laminated to massive. Locally brecciated and recemented. Root holes and small solution voids are common.

TABLE III (continued)

<u>Thickness</u>	<u>Description</u>
8 ft.	<u>Sandstone</u> , fine-to medium-grained, light blue in color, poorly cemented and slightly pumiceous. Angular quartz and andesite grains.

Bottom Elevation: 63 feet

Older Alluvium. The term Older Alluvium as used here refers to the post-Mehrten deposits including the Victor formation described in U.S.G.S. Water Supply Paper 780. These deposits, shown on Plate II by the symbol Qoal, include sands, gravels and semi-indurated siltstone. The materials classified in this category represent several different stages of deposition but are essentially composed of the same type of material. In the sands and gravels the chief characteristics are high percentage of quartz and the red color due to iron oxides. The presence of considerable bleached mica, the general lower degree of consolidation, and the stratigraphic position all help to distinguish this material from the older formations. The Older Alluvium deposits are chiefly the result of river deposition and lateral variation over short distances is common. That is, the texture of the material varies widely.

The Older Alluvium forms a veneer over much of the reservoir area. East of Dike No. 1 the ridge is capped by 20 to 30 feet of sands and gravel which have been worked for their gold content and are now largely left as dredge tailings. Within the reservoir proper and at the dam site the Older Alluvium appears to have been deposited by the ancestral Mokelumne River located in essentially the same channel that it follows at present. A period of aggradation by the ancient Mokelumne River built up the relatively flat areas that exist upstream and downstream of the axis and buried much of the low relief of the older topography.

It is likely that at one time Bear Creek entered the Mokelumne River through a gap in the vicinity of Dike No. 2 near Drill Hole 110. Drilling shows that more than 85 feet of Older Alluvium overlies the Mehrten formation in this area which was encountered at elevation 100.

Alluvium. The alluvium consists of unconsolidated gravel, sand, silt and clay. The material varies from large boulders and cobbles of the dredge tailings to the silts and clays of the recent flood-plain deposits. Alluvium in the area occurs primarily as stream deposits and also as a thin veneer of fine-grained deposits covering several levels of terraces. Much of the area near the Mokelumne River has been reworked during two or three periods of dredging operations.

IV - ENGINEERING GEOLOGY

Dam Site. The axis of the dam is in a relatively narrow valley some 1,200 feet wide carved through a mudflow-capped ridge in the Mehrten formation. River elevation at the dam site is approximately *248' on p. 4.* 95 feet above sea level and the crest elevation of the proposed dam is 248 feet. The slope of the abutments steepens near the river from the relatively flat-topped crests to a 40 foot vertical cliff on the left abutment. The river section contains dredge tailings composed of cobbles underlain by a zone of finer materials, predominately sand-size particles. For a geologic section along the axis, refer to Section **AA**, Plate III.

Right Abutment

The right abutment is composed of two formations, the Mehrten and the Older Alluvium. Much of the rock is well exposed for surface inspection. Four 5-1/2 inch diameter diamond core holes were drilled to explore the abutment foundation, numbers DH-119 and 120 along a proposed axis line, and numbers DH-117, 118 and 119 along the outlet works line.

Mapping showed three separate mudflows on this abutment; one capping the hill about elevation 300 feet; a second in a partially eroded channel-fill on the west side of the hill between elevations 210 and 280; and a third, consisting of one or more fine-grained, thin flows in the 180

through 200 foot interval. This third or lower interval of mudflow is approximately at the gradational contact between the coarser grained sediments such as the conglomerates and sandstones above, and the generally finer grained sediments below. This group of mudflows largely controls the spring seepage on this abutment. The thin-bedded flows pinch-out about 800 feet east of the axis and are cut off by contemporaneous Mehrten erosion approximately the same distance northwest of the axis.

Hole DH-120 was located in the Mehrten formation, but holes DH-117, 118 and 119 penetrated the Older Alluvium to varying depths before reaching the Mehrten formation. The Older Alluvium on this abutment varies from silty, fine-grained sandstone to conglomerate. In the drill holes, the sandstones encountered were very soft and poorly cemented, although semi-indurated silty sands crop out near by. Hole DH-117 (downstream of the outlet works discharge structure) penetrated Older Alluvium to a depth of 36 feet, the lower 16 feet of which was a very poorly cemented pebble-to cobble-size conglomerate. In this hole, the Older Alluvium was found to elevation 83, lower than at any other point of exploration. The highest of the Older Alluvium outcrops in the vicinity of the dam is at elevation 160 feet which indicates that the present river had to cut its way through at least 77 feet of Older Alluvium sediments to exhume its old channel.

The outlet works as presently envisioned is located on the right abutment and is to be constructed by cut and cover methods. The excavation for this conduit will be primarily in the Older Alluvium, but the foundation should be within the Mehrten formation. Between the centerline of the axis and the outlet structure, the excavation will be through Mehrten deposits as much as 30 feet above conduit invert. For a geologic section along the outlet structure, refer to Section B-B, Plate III.

Cut slopes in the Mehrten mudflow material will stand satisfactorily on slopes of 1 horizontal to 4 vertical; however, in the claystones, siltstones, sandstones, and conglomerates slopes of 1 to 2 are recommended. Temporary construction slopes of 1 horizontal to 4 vertical should be satisfactory in these materials. Cut slopes in the Older Alluvium should be stable at about 1 to 1; however, berms will probably be required for cuts exceeding 40 feet in height.

River Section. Three formations were encountered in the river section drilling; the recent alluvium, which is about 30 feet thick and extends down to the 80 foot elevation; the Mehrten formation which extends to the 20 foot elevation; and the Valley Springs formation which extends below the depth of drilling. The recent alluvium consists almost entirely of reworked river sands and gravels which are now in the form of dredge tailings. The Mehrten formation is composed of claystones, siltstones,

and fine-to medium-grained sandstones. No conglomerates or coarse-grained sandstones were noted in this interval of the Mehrten. The claystones and siltstones generally cored well and were firm and often jointed. Root holes and local rehealed brecciated zones were also quite prominent. Sandstones were often silty and varied from very firm to friable.

The contact between the Mehrten and the Valley Springs formations in this area is within fine-grained members and rather indistinct. In drill holes 108 and 109 an erosional contact was noted but in holes DH 105 and 107 this feature could not be identified. In general the contact zone is expected to be relatively impervious.

The Valley Springs formation was encountered in all the river section drill holes and consisted of light colored claystones, siltstones, volcanic tuffs, fine-to coarse-grained sandstones and a trace of black organic shale. In general the beds in the Valley Springs are much less lenticular than those of the Mehrten formation, and consequently easier to correlate from hole to hole. Dip and strike determinations made on two of the more continuous Valley Springs beds as determined from drilling in the channel section give the following: N 20° W to N 40° W for the strike, and a dip of about one degree to the southwest.

Left Abutment

Exploration on this abutment consisted of two core holes, DH- 121 and 101, detailed mapping and logging of an existing inclined adit-shaft located near river level and slightly downstream of the axis. The only formation exposed on this abutment is the Mehrten. It is composed of a very thick mudflow cap underlain by a relatively coarse zone which is underlain by a sequence of mudflows and sandstones and siltstones. A nearly vertical cliff rises from a debris covered base at flood-plain level to about elevation 150. Light colored siltstones, fine- to medium-grained sandstones and claystones are exposed in the cliff face. Drill Hole DH-105 near the base of this cliff indicates that a similar sequence is present below the flood-plain level and extends down to the contact with the Valley Springs formation at an elevation of about 20 feet. A well cemented zone composed generally of fine-grained mudflow material lies above this finer zone. The sediments overlying the mudflow units are somewhat coarser and include some medium-to coarse-grained sandstones and conglomerate.

A series of small springs occurs on this abutment slightly above the contact between the thin mudflow unit and the sandstone. Their presence is believed related to the decreasing permeability of the Mehrten formation at this horizon. A pebble-boulder mudflow with a base elevation varying between 195 and 220 feet caps the abutment. In general the mudflow deposits are poorly sorted, well cemented, and

relatively impervious. Occasional sandstone and conglomerate stringers representing stream sorting and deposition between mudflows are present in this unit capping the abutment.

Dike No. 1

Dike No. 1 is the eastern-most dike on the south side of the reservoir and extends for about 7000 feet across four draws and three small rises to the eastern end of Dike 2, (see Plate XI, section JJ). Over the two eastern-most draws, the dike will reach a height of 80 feet and over the two western-most draws a height of about 65 to 70 feet. The eastern-most abutment will consist of siltstones and fine-to medium-grained sandstone of the Mehrten formation above elevation 220. Continuing west from the base of the Mehrten across the road to the town of Camanche and to the 180 foot contour at the base of the first rise, the material is entirely within the Valley Springs formation. Surface exposures of the Valley Springs formation along the dike are composed primarily of a white vitric tuff which has been case-hardened. Friable sands which are within the Valley Springs formation are exposed for about 300 feet along the sides of a small ravine just north of the road to the town of Camanche. These sands were not found elsewhere in the area and are believed to be a local occurrence. From the 180 foot contour on the east side of this rise to the 200 foot contour on the west side, the materials are the rust colored, quartzose sands of the Older

Alluvium. This material has been removed by erosion to the north but thickens to the southwest of the proposed dike line. Continuing west from the 200 foot contour on the west side of the first rise, the white tuffs of the Valley Springs formation crop out for the next 400 to 500 feet, until they dip under a thickening section of the Mehrten formation. From this point west, which is approximately 200 feet east of the San Joaquin County line, Dike No. 1 would be founded in the Mehrten formation composed largely of siltstones, claystones and fine-grained sandstones.

Three core holes, numbers DH-114, 115, 116 and one auger hole, number A-11, were drilled and logged at Dike No. 1. Also three existing wells in the area, numbers 1, 2 and 3 were logged. Surface exposures were generally good and the dike line was mapped in detail. Occasional dozer trenches were excavated to augment the natural surface exposures.

Dike No. 2

Dike No. 2 is the longest of the 6 dikes, about 8,700 feet in length, and has a maximum height of 70 feet. Its foundation will be composed of three formations: the Valley Springs, the Mehrten, and the Older Alluvium. Six diamond core holes were drilled along the dike line for a total depth of 454 feet. Additional exploration consisted of ten bucket auger holes and three Denison core holes to bedrock, eight dozer trenches, detailed field mapping, and information obtained

by logging an old 65 foot deep dug well and spillway hole DH-101.

The western portions of the dike in the vicinity of the spillway, and in the area near drill hole DH-110 are founded directly on mudflows of the Mehrten formation or included thin conglomerate lenses. Water tests of core holes DH-104 and 106 in this area indicated that the subsurface material is relatively impervious. Below elevation 180 on the reservoir side of the dike there occur clayey sands of the Older Alluvium and a soil mantle that forms a natural blanket along this interval.

The dike changes alignment near hole DH-110 from its southeasterly bearing and swings to the east. The swale between this change in alignment and hole DH-111 is somewhat complex as may be seen on the geologic section H-H, Plate V. The abutment near hole DH-110 is composed of sandstone and siltstone which appears to be relatively impervious. The center of a buried channel is about 150 feet east of hole DH-110. Exploratory work with the bucket auger and drilling using a Denison barrel sampler showed this channel to bottom about elevation 110 at the western end, becoming shallower near Hole DH-111. The channel was cut into sandstone of the Mehrten formation. The material filling this channel is the Older Alluvium composed of moderately sorted fine-to coarse-grained sand in a clay to silt matrix. There are occasional sand and gravel zones. As this material was stream deposited, considerable

lateral variation in grain size exists. Nineteen Denison tube samples were laboratory tested for density and shear strength. The dike location has been aligned to take advantage of the shallowest bedrock in the area.

Dike No. 3

This dike is founded entirely on the exposed hard mudflow capping the left abutment and is primarily a freeboard dike. Exploration of this site was limited to surface study.

Dike No. 4

One diamond core hole was drilled along the centerline of the axis and a dozer cut was made on the left abutment of the dike and angled down across the north side of the saddle on which the dike is founded. The materials beneath the axis of the dike and the abutments are moderately well cemented Mehrten sandstone and siltstones with the exception of the base of the saddle which is a 10 foot thick mudflow grading into pebble conglomerate. Water testing the core hole between elevation 185 and 163 indicated a zone of high permeability. This pervious zone is sealed off, however, by a natural blanket of Older Alluvium and silty slope wash present above and below these elevations.

Dike No. 5

Drill Hole DH-122 was drilled along the centerline of the axis and a dozer cut made down the left abutment. Bedrock under the channel

section and the left abutment is composed of moderately well cemented sandstone of the Mehrten formation to a depth of 45 feet where tuffaceous sandstone of the Valley Springs formation is penetrated. The right abutment is composed of tight sandstones of both the Mehrten and Valley Springs formations.

The contact of these two formations is strikingly apparent in this area. The exposure exhibits the western wall of an old Valley Springs channel that has been filled by Mehrten deposition. The contact has been case-hardened and now is a relatively resistant ridge that strikes to the southwest and dips approximately 30 degrees to the southeast. In Drill Hole DH-122 the same contact was penetrated at a depth of 45 feet.

Dike No. 6

One diamond core hole DH-123 was drilled and two dozer trenches excavated along the alignment of this dike.

The abutments consist of firm, interbedded fine-grained sandstones and siltstones of the Mehrten formation beneath a thin soil cover averaging less than one foot in thickness. The channel section of the dike is founded on a series of poorly cemented sandstone and conglomerate beds of the Mehrten formation.

Stripping

It is estimated that the amount of stripping required under the main dam section will be rather small. Stripping for the core trench should penetrate into the Mehrten formation approximately 2 feet deep to remove surface weathered and loose blocks. The abutment slopes are very steep, in places overhanging, and hence will require shaping.

In the channel area an estimated 30 feet of dredge tailings will have to be removed beneath the core section.

Estimated stripping depths for the shell section are:

Right Abutment.

<u>Zone</u>	<u>Stripping Estimate</u>
Flood-plain (elevation 100) to 125 foot contour.	5 ft.
125 to 200 foot contour.	2 to 3 ft.
200 to 250 foot contour.	1 to 2 ft.

River Section. Remove pockets of organic materials and silts ponded in tailings.

Left Abutment.

<u>Zone</u>	<u>Stripping Estimate</u>
Flood-plain (elevation 100) to 150 foot contour.	1 to 10 ft.
150 to 215 foot contour.	1 to 3 ft.
215 to 250 foot contour.	Less than 1 ft.

Dikes. Stripping depths for the core zone along the dike alignments are estimated to average between 1 and 2 feet into the Valley Springs or Mehrten formation. This excavation should remove the open jointed foundation rock material near the surface. In areas where the overburden material above foundation rock is greater than a few feet, individual considerations on foundation excavation requirements will be made. Where the natural soil blanket occurs it should be left undisturbed on the reservoir side of the dike line. Wells within the reservoir should be plugged.

V - SPILLWAY

The spillway is to be located on the left abutment some 1,100 feet south of the crest of the dam and between Dikes 2 and 3. Investigation along the spillway consisted of three core holes (DH-101, 102 and 103), three auger holes (A-12, 13 and 18), dozer trenches, and surface mapping. Two additional core holes are currently being drilled at the crest structure location to obtain foundation information.

The lined portion of the spillway and the spillway approach will be entirely within the Mehrten formation. Water from the spillway will discharge onto firm Mehrten sandstones. This material should not erode excessively under conditions of moderate flow; however, the material will erode to some extent to form a natural stilling pool.

Surface exposures and information obtained from auger holes A-13 and 18 indicate that the base of the pilot channel will be in Mehrten sandstone and siltstones. The cut slopes are expected to be largely in poorly consolidated deposits of Older Alluvium.

Cut slopes in the Mehrten mudflow material elsewhere stand satisfactorily on slopes of 1 horizontal to 4 vertical in the claystones, siltstones, sandstones, and conglomerates; slopes of 1 to 2 are stable. Temporary construction slopes of 1 horizontal to 4 vertical should also be stable. But slopes in the Older Alluvium should be stable at 1-1/2 horizontal to 1 vertical, although these slopes may erode readily.

VI - SEISMICITY

Faults along which earthquakes of destructive intensity have originated are present to the east along the eastern edges of the Sierras and to the west of the San Francisco Bay region. Earthquakes of minor intensity have also been known to originate to the north in the Grass Valley-Nevada City area. Historic record for the Mokelumne River area, however, does not indicate that any earthquakes of strong intensity have been felt. During the detailed mapping of the area no evidence of faults indicative of earthquake activity was found in any of the post-Cretaceous rocks. Considering the location of the dam relative to known centers of seismic activity and the characteristics of the underlying foundation material an earthquake design factor of 0.1g is ample.

VII - RIPRAP

An investigation of possible sources of riprap was conducted in the vicinity of the dam site. Two sites located in the areas of crystalline rocks were selected for drilling. The location of the two quarry sites and the geologic logs of the six drill holes are shown on Plate XIII.

Quarry site No. 1 is located near State Highway 88 about 11 miles north of the axis of the dam. Three NX size diamond core holes totalling 293 feet were drilled at Quarry No. 1. Two of the holes were angled 40 degrees from the horizontal and a third was vertical. The volume of rock under investigation is approximately 400,000 cubic yards with a possible additional 500,000 cubic yards available adjacent to the delineated quarry area.

The rock is massive, dense, metamorphosed volcanic material of Jurassic age frequently referred to as "greenstone". A summary of the physical properties of the rock is shown in Table IV. The predominate joints strike N 40° E and N 30° W and both dip about 80 degrees to the west. The distance between joints averages about 1.5 to 2.0 feet. Secondary joints lie nearly horizontal and are spaced approximately 5 feet apart. This joint pattern indicates that blasting should produce tabular shaped blocks about 1 to 2 cubic feet in size. There is very little overburden to remove except at the base of the slope where the outcrop

plunges beneath the meadow. Removal of this overburden can be eliminated by raising the base of the quarry 15 feet and broadening it eastward out of the area investigated if additional volume is required.

Quarry site No. 2 is located approximately 11 road miles from the axis of the dam along the road to Campo Seco in the vicinity of McFinnerty Gulch. Surface outcrops indicated that the natural rock is of similar rock type but of poorer quality than that of quarry site No. 1. Three NX size core holes were drilled for a total of 198 feet. One hole was angled 40 degrees from the horizontal and two were vertical. The rock encountered in two holes was very badly fractured and deeply weathered, partially altered to clay. The third hole contained hard, dense, very badly fractured rock with the fractures spaced approximately 8 to 10 inches apart cut by a vertical joint pattern spaced approximately 1 foot apart. There were numerous secondary fractures at many angles. The overburden averages approximately 12 to 15 feet in thickness. The volume of rock outlined by drilling and surface outcrops is approximately 450,000 cubic yards. It is estimated that a large quantity of this material, perhaps 50 percent, would not be suitable for riprap.

VIII - CONCRETE AGGREGATE

Petrographic examinations were completed for Mokelumne River aggregates from three sources near the Camanche Dam site. These were: (1) Claude E. Wood Company Gravel Plant located about five miles downstream from the dam site axis, T 4 N, R 8 E, Section 16; and (2) the Teichert Plant site located about three miles downstream from axis, T 4 N, R 8 E, Section 11; and (3) a potential site, site No. 3, located about four miles upstream from the axis, T 4 N, R 9 E, Section 11.

A study of the Mokelumne River aggregates was recently completed by the Corps of Engineers, Sacramento District and the results of this study are reported in appendices accompanying the Corps "Design Memorandum No. 4, New Hogan Project, Calaveras River, California". The Corps of Engineers test data given in that report were used in evaluating the aggregates in our present study.

Aggregate Record

The performance record of Mokelumne River aggregates used for the construction of Pardee Dam indicates they are not chemically reactive with the type cement used there. The source of these concrete aggregates was a deposit located approximately 15 miles upstream from the Camanche Dam site. Aggregates from this source have a satisfactory performance record with a minor exception. The deposit apparently contained siltstone

bearing pyrite which caused occasional surface pits, pop-outs, and iron stain to occur on the surface of the concrete at the dam. These deleterious siltstones are not present in the three samples obtained from the deposits near the Camanche Dam site.

Preliminary Petrographic Analyses

Coarse aggregate samples from three sources were examined megascopically and with a stereo-microscope. The fine aggregate was examined microscopically. The rock and mineral components of the samples were identified and tabulated by weight.

Coarse Aggregate. The coarse aggregates from the three sources contained particles varied in shape between well rounded and sub-angular. The material is composed primarily of quartzite with lesser amounts of schists, meta-volcanics, several types of igneous rocks, and quartz. A summary of the relative percentages of the various rock types of the coarse aggregate is given below.

COARSE AGGREGATE

Rock Type	Source					
	C. C. Wood Plant		Teichert Plant Site		Site No. 3	
	1/4" to 3/4"	3/4" to 1-1/2"	1/4" to 3/4"	3/4" to 1-1/2"	1/4" to 3/4"	3/4" to 1-1/2"
Acid Igneous	1	13	10	12	3	15
Quartz	16	2	15	6	15	1
Volcanic	0	3	0	2	0	T
Quartzite	33	33	26	37	28	32
Schist	17	12	18	13	20	26
*Meta-rocks	33	37	31	30	34	26
Total	100	100	100	100	100	100

Fine Aggregate. Samples of the fine aggregate from the three Mokelumne River sources are of the same general rock types as those found in the coarse aggregate. The particle shapes are sub-rounded to angular and generally fresh and unweathered. The particles are composed largely of quartz with smaller amounts of feldspar, mica, ferromagnesian minerals and undifferentiated metamorphic rocks. A summary of the relative percentages of the various quantities is listed below.

* Undifferentiated metamorphic rocks.

FINE AGGREGATE

Mineral	: C. C. Wood Plant	: Teichert Plant Site	: Site No. 3 :
Quartz	83	82	85
Feldspar	7	10	5
Mica	1	1	1
Ferromagnesian	2	2	1
Magnetite	4	3	4
* Meta-rock	3	2	4
Total	100	100	100

Conclusion

The samples analyzed are petrographically satisfactory for concrete aggregate. They are generally non-reactive or innocuous, but the U. S. Corps of Engineers found that selected samples of volcanic rocks from deposits along this reach of the Mokelumne River had a deleterious reaction by the quick chemical test. Therefore, it is recommended that a low alkali cement be utilized. Type II low alkali (State) cement having a maximum alkali, expressed as sodium oxide equivalent, of less than .6% by weight is available in the area at no additional cost.

* Undifferentiated metamorphic rocks.

IX - ROCK PROPERTIES

Table IV contains a summary of the results of laboratory permeability tests, unconfined compressive tests and specific gravity determinations of various core samples.

Permeability Tests

Approximately 100 tests were performed to determine the vertical and horizontal permeabilities of selected core samples. A large portion of the samples were composed of sandstone. These were selected because this type of material was expected to be more permeable than other types. The samples were 4-inch diameter core obtained with a "C" series core barrel using a specially designed face discharge bit. Samples were cut to 2-1/2 inch cubes and placed in a square permeameter. The samples were saturated from the bottom using distilled and de-aired water at room temperatures. Permeability determinations were made using the falling head method. Maximum hydraulic test gradient was 20 and the average was 12. The results indicate the ratio of horizontal to vertical permeabilities ranged from less than 1 to 1 to over 300 to 1.

Specific Gravity and Density

Specific gravity determinations were made on samples of Mehrten sand and conglomerate. The results ranged from 2.65 to 2.72 and averaged 2.69. Dry densities of these materials ranged from 104 to 136 lbs./ft.³ and averaged 125.

TABLE IV
ROCK PROPERTIES

Material	Permeability (feet per year) ⁽¹⁾								Specific Gravity ⁽²⁾		Unconfined Compressive Strength (pounds per square inch) ^{(2) & (3)}				
	Horizontal				Vertical				No. of Samples	Aver.	No. of Samples	Aver.	Min.	Max.	Aver.
	No. of Samples	Min.	Max.	Aver.	No. of Samples	Min.	Max.	Aver.							
Mehrten Formation	Sandstone	53	0.3	3000	305	48	0	5500	200	2	2.69	7	483 ⁽⁴⁾	1845	890
	Siltstone	5	0.5	16.8	6.2	5	0.4	13	4.2						
	Conglomerate	2	0.8	1391	696	2	0.6	126	63.3	2	2.69	5	267 ⁽⁵⁾	1590	910
	Tuff	1	-	-	2050	1	-	-	6.0			-	-	-	-
	Mudflow	1	-	-	0.5	1	-	-	1.6			7	898	4270	1535
	Claystone											3	112	1170	550
"Greenstone" (Quarry No. 1)	-	-	-	-	-	-	-	-	-	2	2.72	9	8700	42,120	24,365

(1) Tests performed by Bechtel Corporation, Pollock Pines.

(2) Tests performed by Hales Testing Laboratory, Oakland.

(3) Tests performed by McCreary · Koretsky Laboratory, San Francisco.

(4) A value of 113 psi was obtained in one test, results not included in table as the sample was not tested until four months after sample was cored.

(5) Value is not representative, this low value may be due to unequal stress distribution.

Samples of rock from Quarry site No. 1 have an average specific gravity of 2.72 and a dry density of 169 lbs./ft.³.

Unconfined Compressive Tests

Unconfined compressive tests were performed on several rock types of the Mehrten formation and material from Quarry site No. 1.

Test results from 23 samples of the Mehrten formation indicated a minimum compressive strength of 112 psi, a maximum of 4270 psi and an average 1050 psi. The minimum shear strength of the mudflow, conglomerate and sandstone members of the Mehrten formation is estimated to be in excess of 100 psi. The estimate is based on the results of 19 unconfined compressive tests.

Test results from nine samples of the rock from Quarry site No. 1 indicate the materials are of superior quality. The compressive strengths ranged from 8,700 to 42,170 psi. The wet shot tests results were 12.7 percent loss after 10,000 revolutions and the percent absorption was less than 1 percent.

X - FIELD PERMEABILITY TESTS

Objective

Field permeability tests were conducted to determine the in-place permeability of foundation materials at Camanche Dam site. The tests were conducted on the left abutment near the spillway alignment and on the right abutment just downstream from the axis. Both the non-equilibrium and the equilibrium methods were utilized in the determinations of the permeability of portions of the Mehrten formation. These permeability data will be used in the seepage studies for Camanche reservoir.

Procedures

The usual ground water pumping tests consist of pumping water from a well and recording drawdowns in observation wells to establish in-place permeabilities. This method is the most accurate method of conducting field permeability tests. Due to the position of the water table with respect to the zones to be tested these pump test methods could not be used at this site. Therefore, a substitute method was used by which water was introduced into the material and the resultant buildup was recorded in observation wells.

An existing 5-foot diameter shaft on the left abutment provided a means by which moderately large quantities of water could be introduced into one of the more permeable zones of the Mehrten formation.

On the right abutment five wells were drilled including a pump-in well as there were no existing large diameter wells or shaft in the area to be tested. The position of the water table with respect to the zone to be tested was quite low and prevented the utilization of the usual pump test methods of determining permeability.

Equipment

Two Marlow centrifugal pumps Model 4 E I S and 4 E I which are powered by gasoline engines were used as a water supply. These pumps were located on the bank of the Mokolunne River.

Two pumps were installed in order to provide stand-by equipment during the constant and prolonged pumping that was anticipated and also to provide continual pumping while one unit was being refueled and serviced. Water was pumped through 8-inch aluminum pipe to the test site. A bypass line was provided near the shaft to convey excess water away from the test site. The water delivered to the shaft was metered through a Trident 4-inch water meter. The dial for the meter was calibrated to read in tenths of a cubic foot. The flow of water at the shaft was accurately measured by recording the metered per hour rate and the total quantity of water introduced.

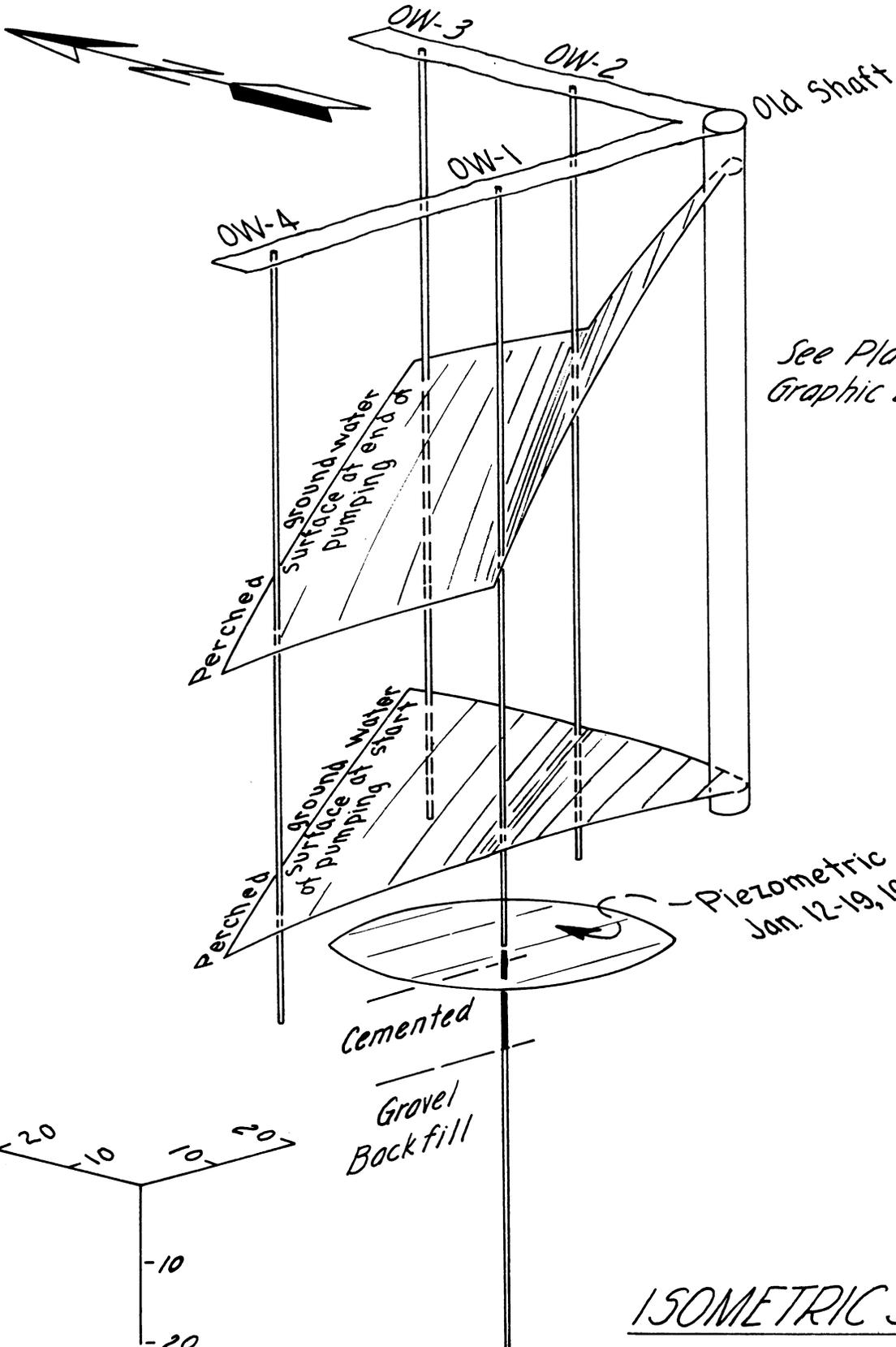
Water surface elevations in the observation wells were recorded on Stevens type ~~S~~^E water stage recorders. The use of this type of equipment provided a continuous record of the water levels in the observation wells prior to the test and all during test periods, and also during the recovery period.

Wells

Wells on the left abutment consisted of an existing shaft approximately 5 feet in diameter and 88 feet deep which was the pump-in well, and four observation wells. The observation wells were 6-inch diameter holes, drilled with a rotary drill utilizing rock bits. Hydrologically the test site consists of two ground-water zones; an upper zone which is free or unconfined and a lower zone which is confined. The unconfined zone, approximately 90 feet thick, occurs between the surface and an aquiclude. The aquiclude or impervious material functions as the confining stratum of the primary water bearing zone. It was decided to test this perched water zone because: (1) water test data obtained during the core drilling program indicated that this was one of the more permeable zones; (2) complete penetration of water bearing zone could be achieved by using the existing shaft. Observation wells No. 1 and No. 4 were located 30 and 60 feet, respectively, from the shaft. Observation wells Nos. 2 and 3, 20 and 40 feet, respectively, from the shaft, were located along a line 90 degrees from the line of wells

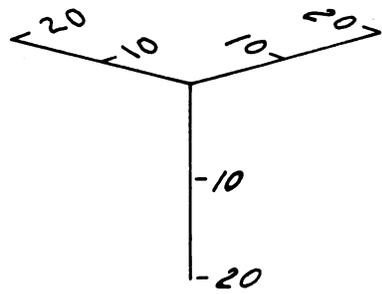
Nos. 1 and 4. Observation wells Nos. 2, 3 and 4 penetrated the permeable portion of the perched zone but did not penetrate the impermeable materials which support a perched water zone. Observation well No. 1 penetrates both a perched zone and the main ground water zone. A piezometer was installed in this observation well to the main water body then a seal was placed between the upper and lower water bearing zones. The upper zone of observation well No. 1 would record the perched water levels, and the deeper zone, the main water level, could be recorded from the piezometer. Water levels were recorded by Stevens type ~~A~~^E water stage recorders and supplemental data on the position of the water level was obtained by measuring the distance to water with a steel tape. Thus the hydrograph of each well was obtained prior to, during the pump test, and after the pumping ceased.

On the right abutment, hole ADH-120 was used as an observation well. This well penetrated both the perched water zone and the main water body. A piezometer was installed to record the water surface of the main water body and the interval between the perched and main water zone was sealed. The upper portion of the well penetrated only the perched water zone. Three additional observation wells were drilled in two lines which were normal to each other. The fifth well was a 6-inch diameter well into which water was pumped.



See Plate XI for Graphic Log of Shaft

Piezometric Surface Jan. 12-19, 1961



Scale in feet

ISOMETRIC SKETCH
FIELD PERMEABILITY TEST

L.A.B. 3-13-61

All observation wells were flushed and cleaned prior to the testing.

Testing Program

Left Abutment. It was planned to conduct a permeability test at the site by pumping water into an existing 5-foot diameter well and recording the resulting ground water levels in 4 observation wells. At least 2 stages or rates of flow were to be used after equilibrium had been approached at the original stage. It was planned to analyze the permeability test data using both the equilibrium and non-equilibrium methods. In addition the usual recovery methods were also to be utilized in evaluating the test data.



Actual testing began January 12, 1961 when water was introduced into the shaft. A flow of approximately 200 gallons per minute was discharged into the shaft and the water surface of the resulting mound was recorded in 4 observation wells. The well locations and the depths are shown in the accompanying sketch (see page 46). Hydrographs of the 4 observation wells are shown on Plate XIV. As noted on this plate a condition that was essentially that of equilibrium was obtained. It was then possible to analyze the permeability data using both the equilibrium and non-equilibrium methods.

Right Abutment. Originally it was planned to conduct a non-equilibrium pump-in test high on the right abutment slightly downstream from the proposed axis of the dam. Drill hole ADH-120 was to be utilized as an observation well in which both the perched water surface and also the main water surface could be observed. Observation well No. 5 is located at a point 60 feet away from drill hole ADH-120 and the pumping well was located along the same line an additional 30 feet away. Observation well No. 7 and 8 were located along a line 90 degrees to the line formed by observation well 5 and ADH-120. Observation well No. 7 was located 20 feet from the pump-in well and observation well No. 8 was located 40 feet from the pump-in well. Water was to be introduced into the pump-in well and the changes in the water surface at the 4 observation wells were to be recorded. Permeability test data would then be analyzed using the non-equilibrium methods. After pumping approximately 24 hours without any change in water surface at even the closest observation well becoming apparent, it was decided to abandon this method of testing. The "slug test" method was then utilized to calculate the permeability in the five wells.

Test Results

A summary of the permeability test results is shown in Table V.

Permeability, in gallons per day, is obtained by dividing the transmissibility (T) by the average thickness (m) of the saturated water bearing material. On the left abutment a thickness of 80 feet was used. This thickness was selected because it is representative of a zone of the Mehrten formation which includes some mudflow material and siltstone as well as the more pervious sandstone and conglomerate.

On the right abutment all of the mudflow cap was excluded from the thickness (m). A small amount of mudflow material which occurs within a sequence of sandstones and conglomerates was included in thickness of the water bearing materials.

TABLE V

RESULTS OF PERMEABILITY TEST
LEFT ABUTMENT

		<u>Non-Equilibrium</u>	
	<u>Equilibrium</u>	<u>Distance-Drawdown</u>	<u>Time-Drawdown</u>
Transmissibility (Rounded)	3465 gpd 3500 gpd	2656 gpd 2700 gpd	3066 gpd 3100 gpd
<u>Permeability</u> (Assuming thickness of 80 feet)	44 gpd/ft ² 2130 ft/yr	33 gpd/ft ² 1620 ft/yr	38 gpd/ft ² 1870 ft/yr

TABLE V (continued)

SLUG TEST RESULTS
RIGHT ABUTMENT

Well	Permeability (feet per year)		
	Max.	Min.	Aver.
OW-5	278	37	142
OW-6	376	64	160
OW-7	326	46	146
OW-8	292	34	127
ADH-120	191	29	81
Average	293	42	131

Last five lines just before (Test Results) in Page 48, implies that perm. is very high, which does not seem so here.

Methods of Analysis

Non-Equilibrium Method. The Theis or non-equilibrium methods are based on an analogy between ground water flow and heat conduction. This analogy is applied to the pumping^{out} of wells and the recording of the drawdown in nearby observation wells or to the introduction of water into a well and the recording of buildup in observation wells.

A detailed discussion of the non-equilibrium method and the development of the Theis formula is found in the United States Geological Survey Water Supply Paper No. 887. To apply this method successfully the water bearing materials should be homogeneous and isotropic, i. e., the materials should have the same physical and hydraulic properties in all directions^{and at all points}. Such conditions are highly improbable in nature

but the laboratory permeability tests on core samples of the main water bearing rocks indicated nearly equal vertical and horizontal permeabilities.

The aquifer theoretically should be of infinite areal extent. It is recognized that such conditions can not be found in nature and as indicated earlier in this report the geologic units are lenticular. Test wells should penetrate the entire water bearing formation and in the tests at Camanche this requirement was fulfilled.

Water level observations were obtained by use of continuous water stage recorders and also distances to water were measured with a steel tape at frequent intervals. In general, the accuracy of results of permeability tests can be evaluated by studying the graphic plots of the drawdown or buildup against distance and time.

The following formulas were used in computing the permeability using this method:

$$T = \frac{114.6 Q W(u)}{s}$$

in which: T = transmissibility,

Q = flow in gallons per minute,

W (u) = the well function,

s = drawdown in feet.

$$P = \frac{T}{m}$$

in which: P = permeability in gallons per day,

m = thickness of the water bearing formation.

Non-Equilibrium, Distance - Drawdown

$$T = \frac{114.6 Q W(u)}{s}$$

$$Q = 197 \text{ gpm} \quad W(u) = 5.3 \quad s = 45$$

$$T = \frac{114.6 (197) 5.3}{45}$$

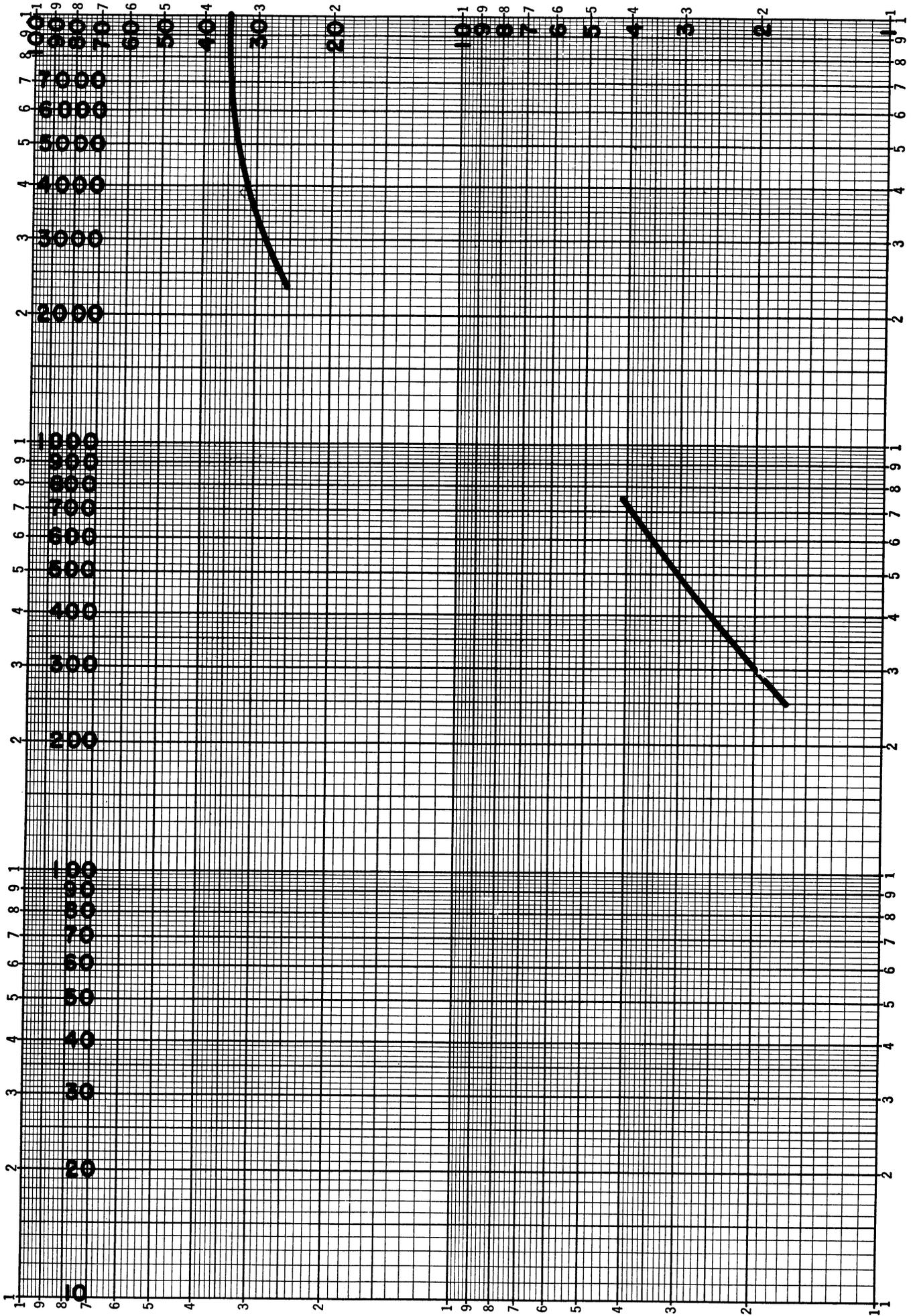
$$T = 2656 \text{ gpd}$$

$$P = \frac{T}{m} = \frac{2656}{80} = 33.2 \text{ gpd/ft}^2 \text{ or}$$

$$P = 1620 \text{ ft/yr.}$$

TIME IN MINUTES

DRAWDOWN IN FEET (s)

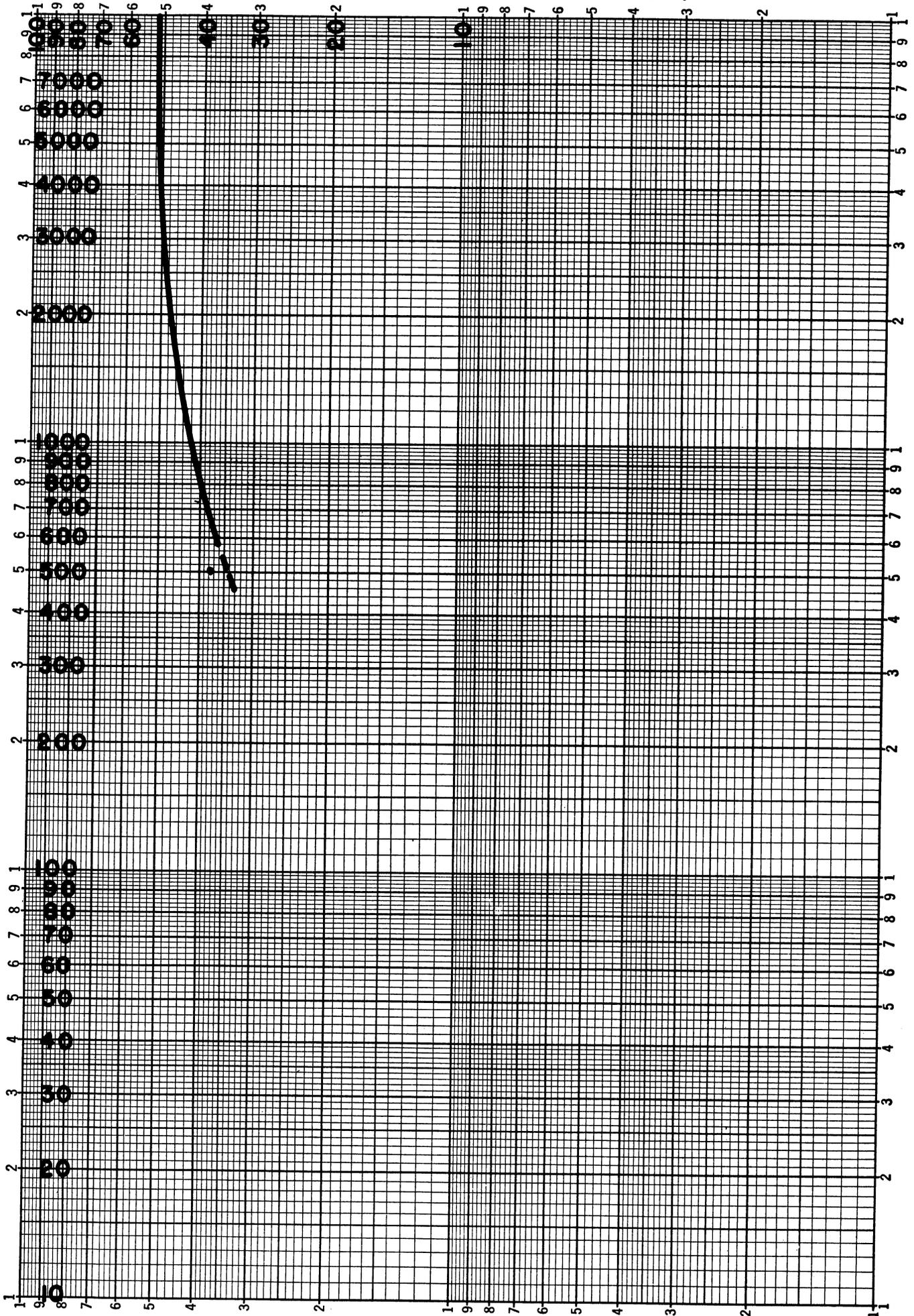


TIME-DRAWDOWN TEST DATA

OW-1

TIME IN MINUTES

DRAWDOWN IN FEET (s)

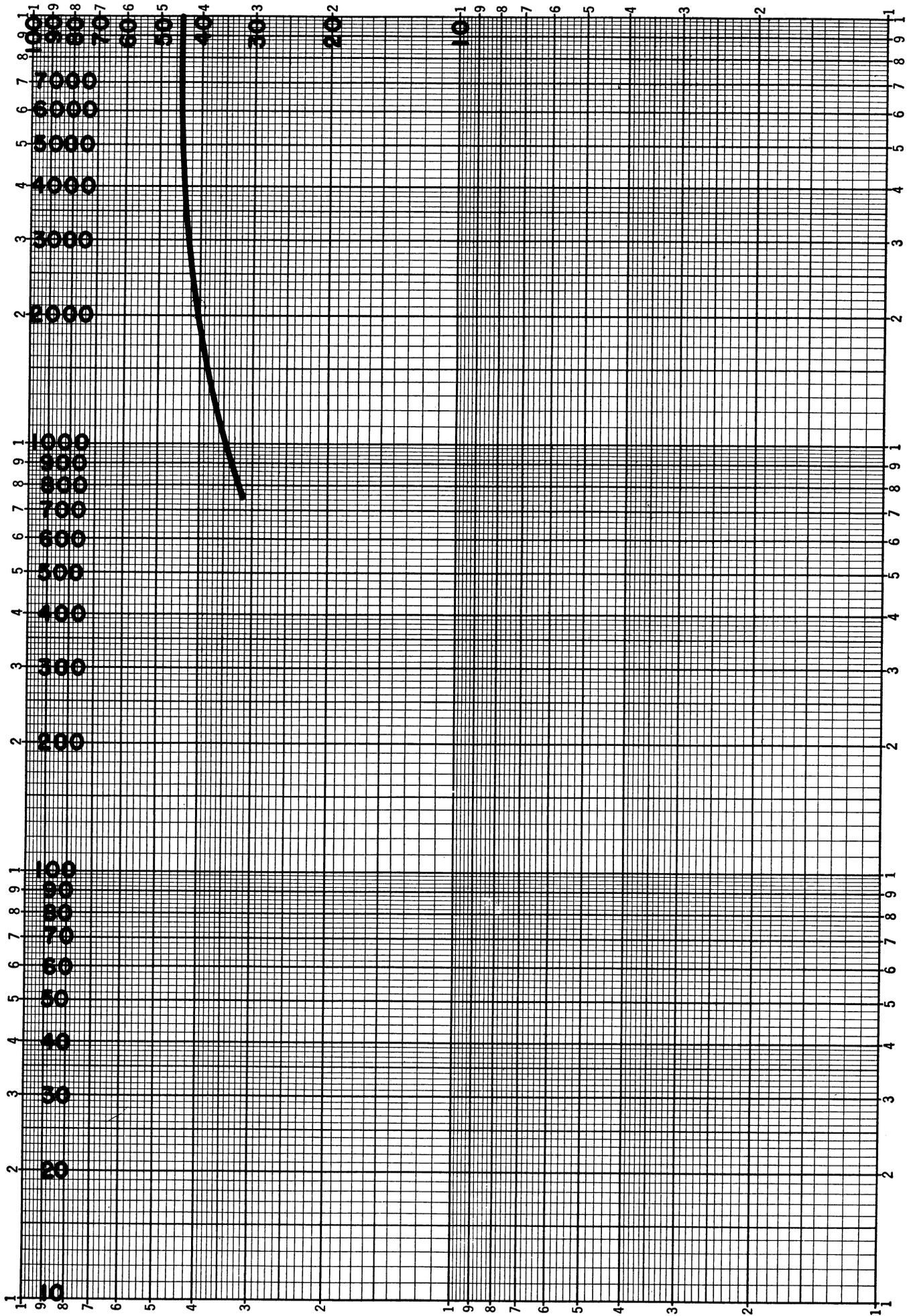


TIME-DRAWDOWN TEST DATA

OW-2

TIME IN MINUTES

DRAWDOWN IN FEET (s)

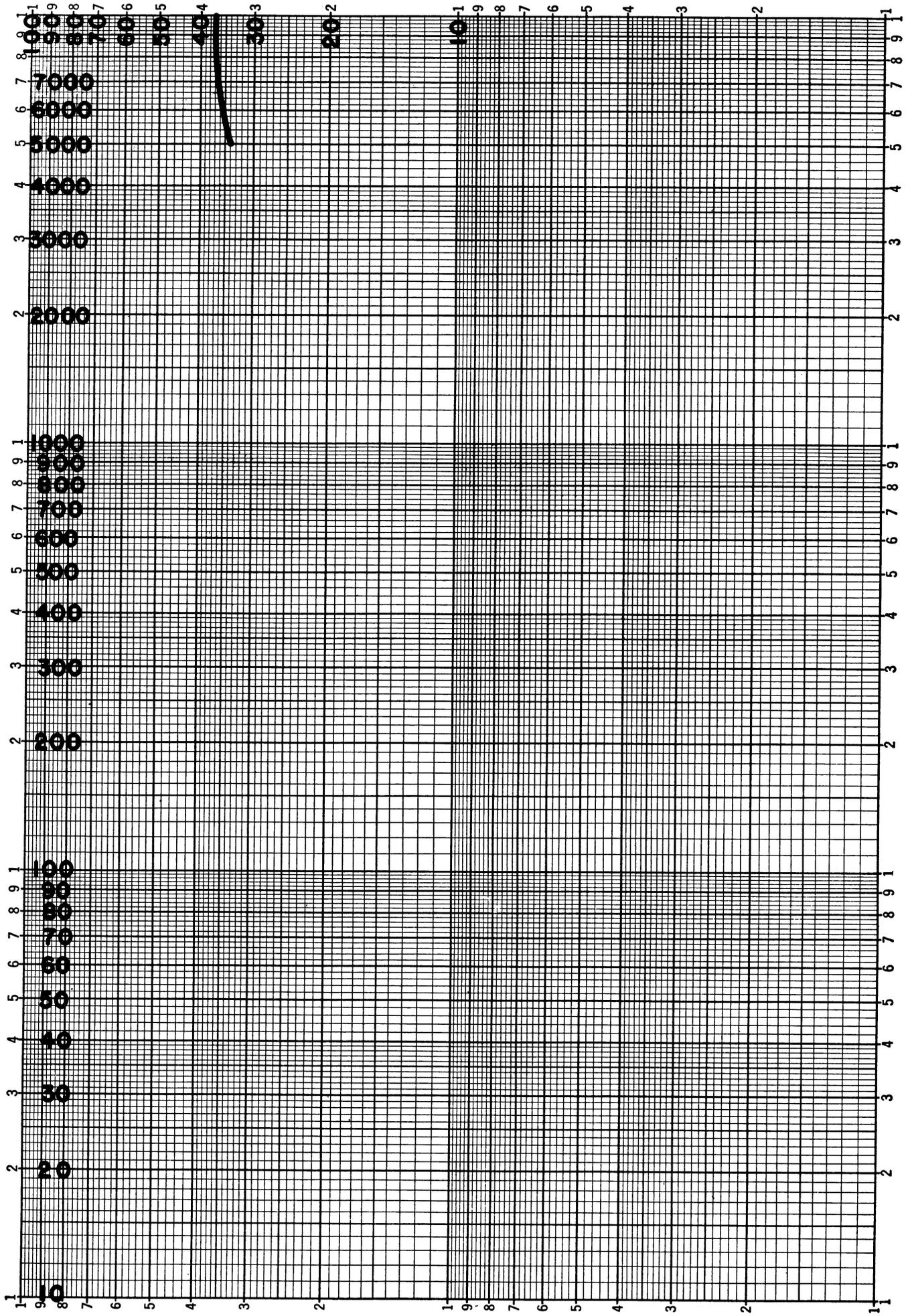


TIME-DRAWDOWN TEST DATA

OW-3

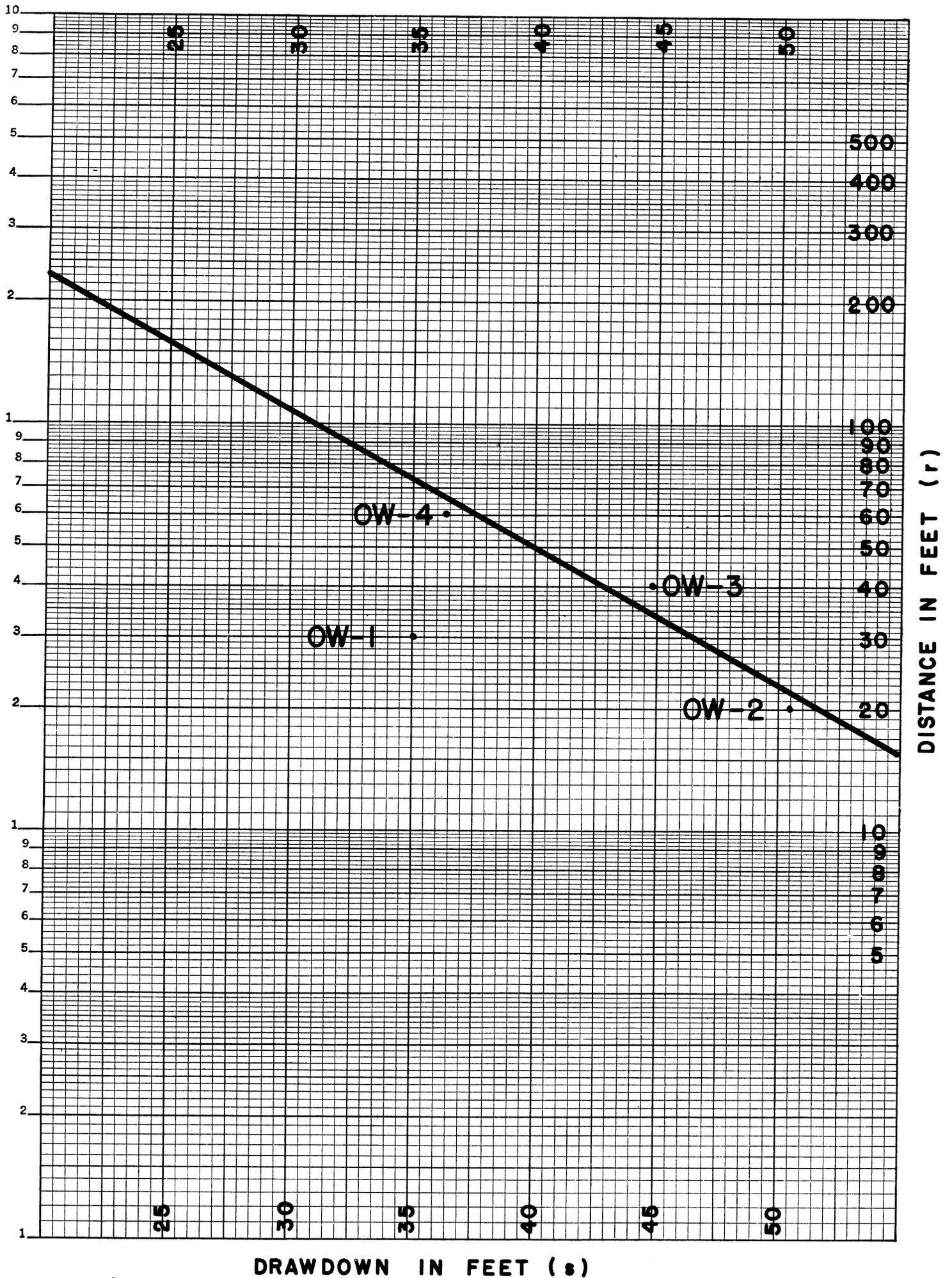
DRAWDOWN IN FEET (s)

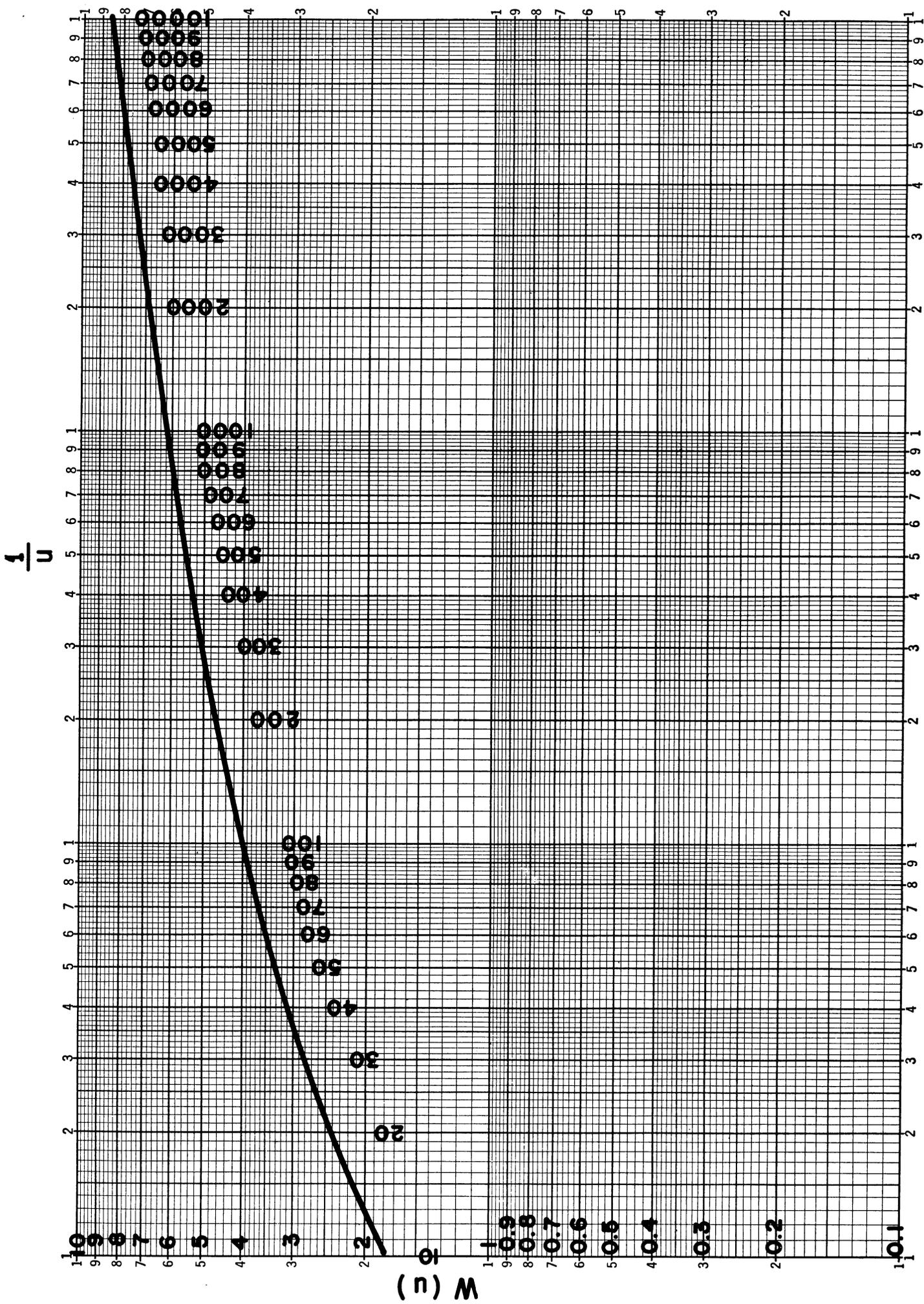
TIME IN MINUTES



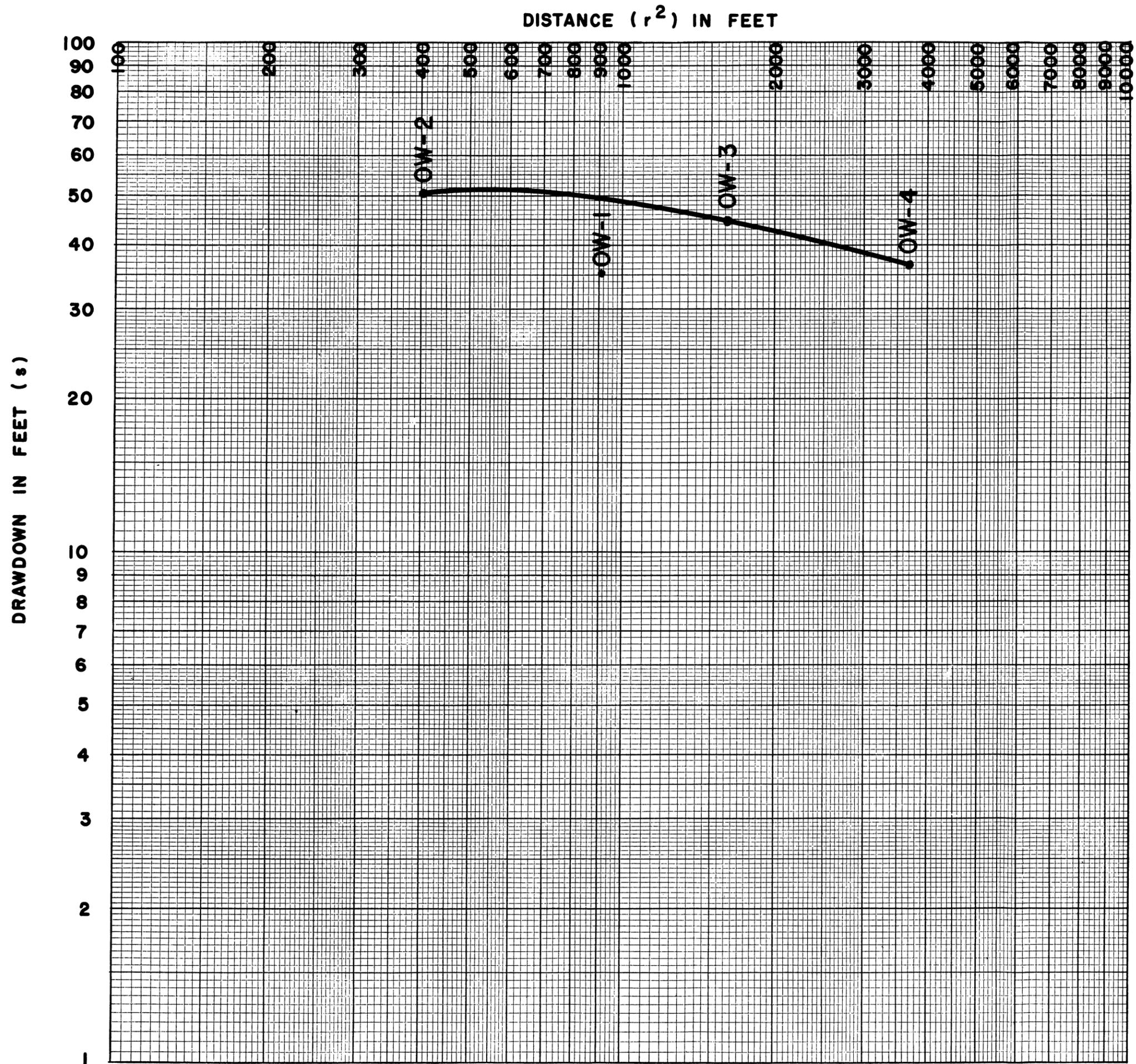
TIME-DRAWDOWN TEST DATA

OW-4

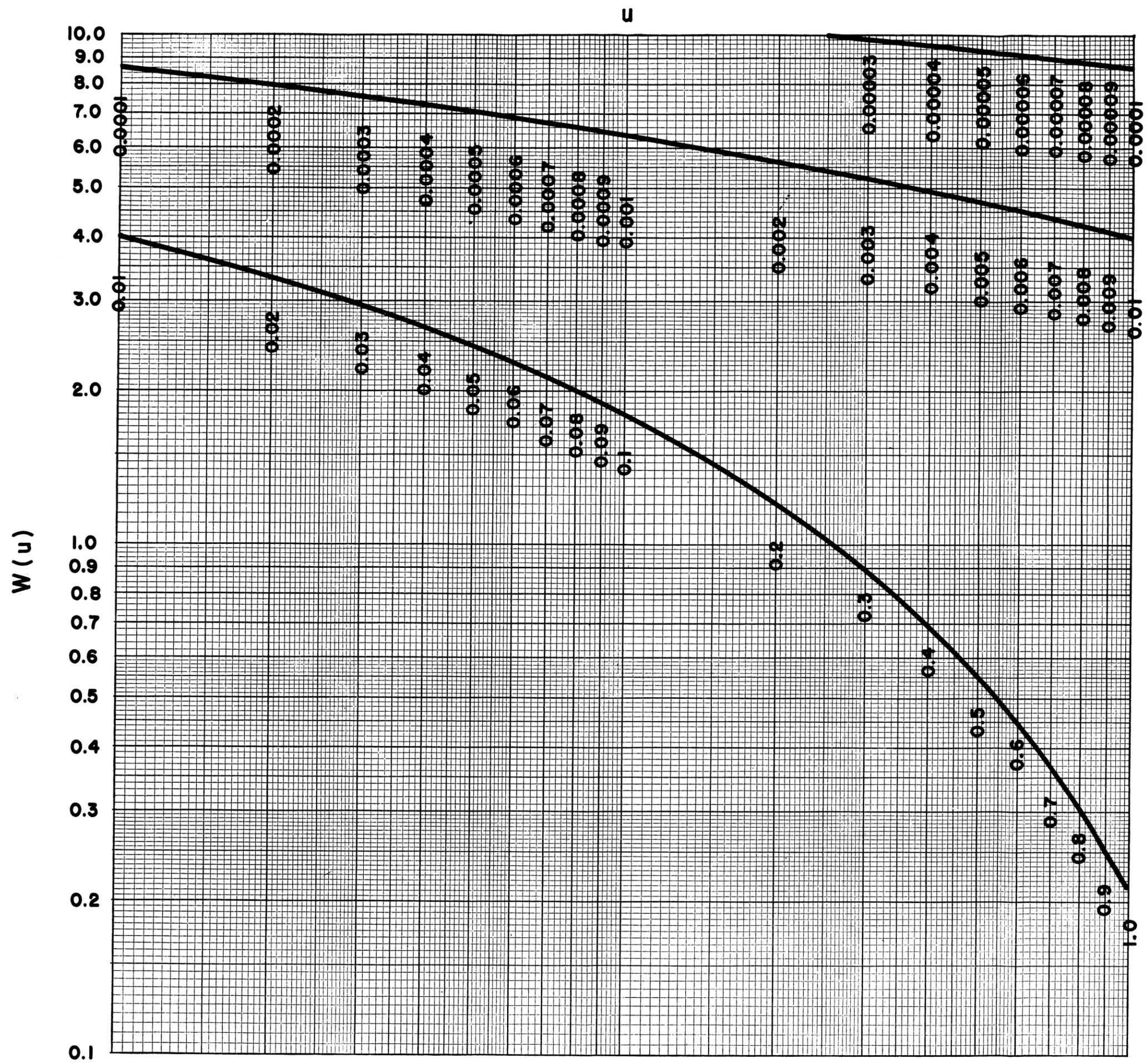




TYPE CURVE FOR NON-EQUILIBRIUM FORMULA



DISTANCE - DRAWDOWN TEST DATA



TYPE CURVE FOR NON-EQUILIBRIUM FORMULA

Non-Equilibrium, Time - Drawdown

$$T = \frac{114.6 Q W(u)}{s} \quad P = \frac{T}{m}$$

Observation Well No. 1

$$T = \frac{114.6 (197) 3.4}{31.5}$$

$$T = 2440 \text{ gpd}$$

$$P = \frac{2440}{80}$$

$$P = 30.4 \text{ gpd/sq.ft. or } 1485 \text{ ft/yr}$$

Observation Well No. 2

$$T = \frac{114.6 (197) 5.5}{45.5}$$

$$T = 2755 \text{ gpd}$$

$$P = \frac{2755}{80}$$

$$P = 34.4 \text{ gpd/sq.ft. or } 1670 \text{ ft/yr}$$

Observation Well No. 3

$$T = \frac{114.6 (197) 5.8}{40.5}$$

$$T = 3230$$

$$P = \frac{3230}{80}$$

$$P = 40.4 \text{ gpd/sq.ft. or } 1970 \text{ ft/yr}$$

Observation Well No. 4

$$T = \frac{114.6 (197) 6.2}{36.5}$$

$$T = 3840$$

$$P = \frac{3840}{80}$$

$$P = 48 \text{ gpd/sq.ft. or } 2340 \text{ ft/yr}$$

Equilibrium Method. The general equilibrium formula is

based on Darcy's Law which may be written as:

$$Q = PIA$$

in which: Q = quantity,

I = the hydraulic gradient,

P = the permeability

A = the area.

In the use of the equilibrium formula I is made unnecessary by the substitution of a factor involving the drawdown of this on the cone of depression. To apply this method successfully the water bearing material should be of uniform permeability and should be underlain by a relatively impermeable formation of infinite areal extent. The well should penetrate to the bottom of the water bearing material. The pump must be operated at a uniform rate of flow during the test period in which the water surface takes the form of a cone around the well. The Thiem formula as derived from Darcy's Law may be expressed:

$$T = \frac{527.7 Q r_2/r_1}{s_1 - s_2}$$

in which: T = transmissibility,

Q = flow in gallons per minute,

m = average of the thickness of the saturated part of the water bearing material at the two observation wells,

r_1 = the distance from the pump well to the near observation well,

r_2 = the distance from the pump well to the distant observation well,

s_1 = the drawdown at the near observation well,

s_2 = the drawdown at the far observation well.

$$P = \frac{T}{m}$$

in which: P = the permeability in gallons per day, per sq.ft.,

T = transmissibility,

m = thickness of the water bearing formation.

The following graphic data and computations were used to determine the permeability at the test site on the left abutment.

$$T = \frac{527.7 Q \log r^2/r^1}{s_1 - s_2}$$

$$Q = 197 \text{ gpm}$$

$$\log r^2/r^1 = \log \frac{200}{20}$$

$$s_1 = 51.75$$

$$s_2 = 21.75$$

$$T = \frac{527.7 (197) \log \frac{200}{20}}{51.75 - 21.75} = \frac{527.7 (197) (1)}{30}$$

$$T = 3465 \text{ gpd}$$

$$P = \frac{T}{m} = \frac{3465}{80}$$

$$P = 43.7 \text{ gpd or } 2133 \text{ ft/yr.}$$

(rounded) $P = 44 \text{ gpd or } 2130 \text{ ft/yr.}$

Slug Test Method. Ferris^{1/} developed a method of determining permeability under special conditions. These conditions are: (1) the transmissibility must be low, that is less than 50,000 gallons per day; and (2) the well must completely penetrate the water bearing material; and (3) the well must be fully screened or uncased. An additional requirement is that the wells be of small diameter.

Ferris utilized the Theis equation $s = \frac{Q}{4T} e^{\frac{-r^2S}{4Tt}}$ the term $\frac{-r^2S}{4Tt}$ can be eliminated where r is very small. Therefore, when this method is used with small diameter wells the expression becomes

$$s = \frac{Q}{4T} .$$

Substitute: $Q = \frac{V}{t}$

then, $T = \frac{114.6 V (1/tm)}{s}$

in which: s = residual head, feet,

Q = flow of water, gpm,

V = volume of water in gallons,

t = time in minutes,

T = transmissibility.

^{1/} John G. Ferris, Hydraulic Engineer, United States Geological Survey, Ground Water Branch.

$$P = \frac{T}{m}$$

in which: P = permeability in gpd/ft² ,

T = transmissibility in gpd,

m = thickness of water bearing formation in feet.

COMPUTATIONS

Slug Test - Well No. OW-5

$$T = \frac{114.6 V (l^3/tm)}{s}$$

$$T_1 = \frac{114.6 (71.6) .667}{29.00} = 189 \text{ gpd}$$

$$T_2 = \frac{114.6 (71.6) .416}{28.60} = 120 \text{ gpd}$$

$$T_3 = \frac{114.6 (71.6) .154}{27.56} = 46 \text{ gpd}$$

$$T_4 = \frac{114.6 (71.6) .80}{26.35} = 25 \text{ gpd}$$

$$P = \frac{T}{m} \quad m = 47.8' - 14.8' = 33.0'$$

$$P_{max} = \frac{T}{m} = \frac{189}{33} = 5.7 \text{ gpd} \text{ or } 278 \text{ ft/yr.}$$

$$P_{aver} = \frac{T}{m} = \frac{95}{33} = 2.9 \text{ gpd or } 142 \text{ ft/yr.}$$

$$P_{min} = \frac{T}{m} = \frac{25}{33} = 0.76 \text{ gpd or } 37 \text{ ft/yr.}$$

Slug Test - Well No. OW-6

$$T = \frac{114.6 V (l^3/tm)}{s}$$

$$T_1 = \frac{114.6 (49.5) 1.05}{21.85} = 273 \text{ gpd}$$

$$T_2 = \frac{114.6 (49.5) .3}{18.60} = 92 \text{ gpd}$$

$$T_3 = \frac{114.6 (49.5) .166}{15.60} = 60 \text{ gpd}$$

$$T_4 = \frac{114.6 (49.5) 0.1}{12.12} = 47 \text{ gpd}$$

$$P = \frac{T}{m} \quad m = 52.1' - 16.7' = 35.4'$$

$$P_{\max} = \frac{273}{35.4} = 7.7 \text{ gpd or } 376 \text{ ft/yr,}$$

$$P_{\text{aver}} = \frac{118}{35.4} = 3.3 \text{ gpd or } 160 \text{ ft/yr,}$$

$$P_{\min} = \frac{36}{35.4} = 1.3 \text{ gpd or } 64 \text{ ft/yr.}$$

Slug Test - Well No. OW-7

$$T = \frac{114.6 V (l/tm)}{s}$$

$$T_1 = \frac{114.6 (84) 1.}{37.75} = 255 \text{ gpd}$$

$$T_2 = \frac{114.6 (84) .490}{35.30} = 134 \text{ gpd}$$

$$T_3 = \frac{114.6 (84) .125}{25.65} = 47 \text{ gpd}$$

$$T_4 = \frac{114.6 (84) .080}{21.42} = 36 \text{ gpd}$$

$$P = \frac{T}{m} \quad m = 56.7' - 18.5' = 38.2'$$

$$P_{\max} = \frac{255}{38.2} = 6.7 \text{ gpd or } 326 \text{ ft/yr,}$$

$$P_{\text{aver}} = \frac{118}{38.2} = 3.0 \text{ gpd or } 146 \text{ ft/yr,}$$

$$P_{\min} = \frac{36}{38.2} = .94 \text{ gpd or } 46 \text{ ft/yr.}$$

Slug Test - Well No. OW-8

$$T = \frac{114.6 V (l/tm)}{s}$$

$$T_1 = \frac{114.6 (113) .926}{49.80} = 240 \text{ gpd}$$

$$T_2 = \frac{114.6 (113) .400}{48.95} = 106 \text{ gpd}$$

$$T_3 = \frac{114.6 (113) .167}{47.69} = 45 \text{ gpd}$$

$$T_4 = \frac{114.6 (113) .100}{46.50} = 28 \text{ gpd}$$

$$P = \frac{T}{m} \quad m = 60.0' - 20.0' = 40.0'$$

$$P_{\max} = \frac{240}{40} = 6 \text{ gpd or } 292 \text{ ft/yr,}$$

$$P_{\text{aver}} = \frac{105}{40} = 2.6 \text{ gpd or } 127 \text{ ft/yr,}$$

$$P_{\min} = \frac{28}{40} = .7 \text{ gpd or } 34 \text{ ft/yr.}$$

Slug Test - Well No. ADH-120

$$T = \frac{114.6 V (l^3/tm)}{s}$$

$$T_1 = \frac{114.6 (69.1) .910}{27.24} = 265 \text{ gpd}$$

$$T_2 = \frac{114.6 (69.1) .300}{23.80} = 100 \text{ gpd}$$

$$T_3 = \frac{114.6 (69.1) .100}{16.94} = 47 \text{ gpd}$$

$$T_4 = \frac{114.6 (69.1) .0705}{13.82} = 40 \text{ gpd}$$

$$P = \frac{T}{m} \quad m = 77.0' - 7.0' = 68.0'$$

$$P_{\max} = \frac{265}{68} = 3.9 \text{ gpd or } 191 \text{ ft/yr,}$$

$$P_{\text{aver}} = \frac{113}{68} = 1.66 \text{ gpd or } 81 \text{ ft/yr,}$$

$$P_{\min} = \frac{40}{68} = .59 \text{ gpd or } 29 \text{ ft/yr.}$$

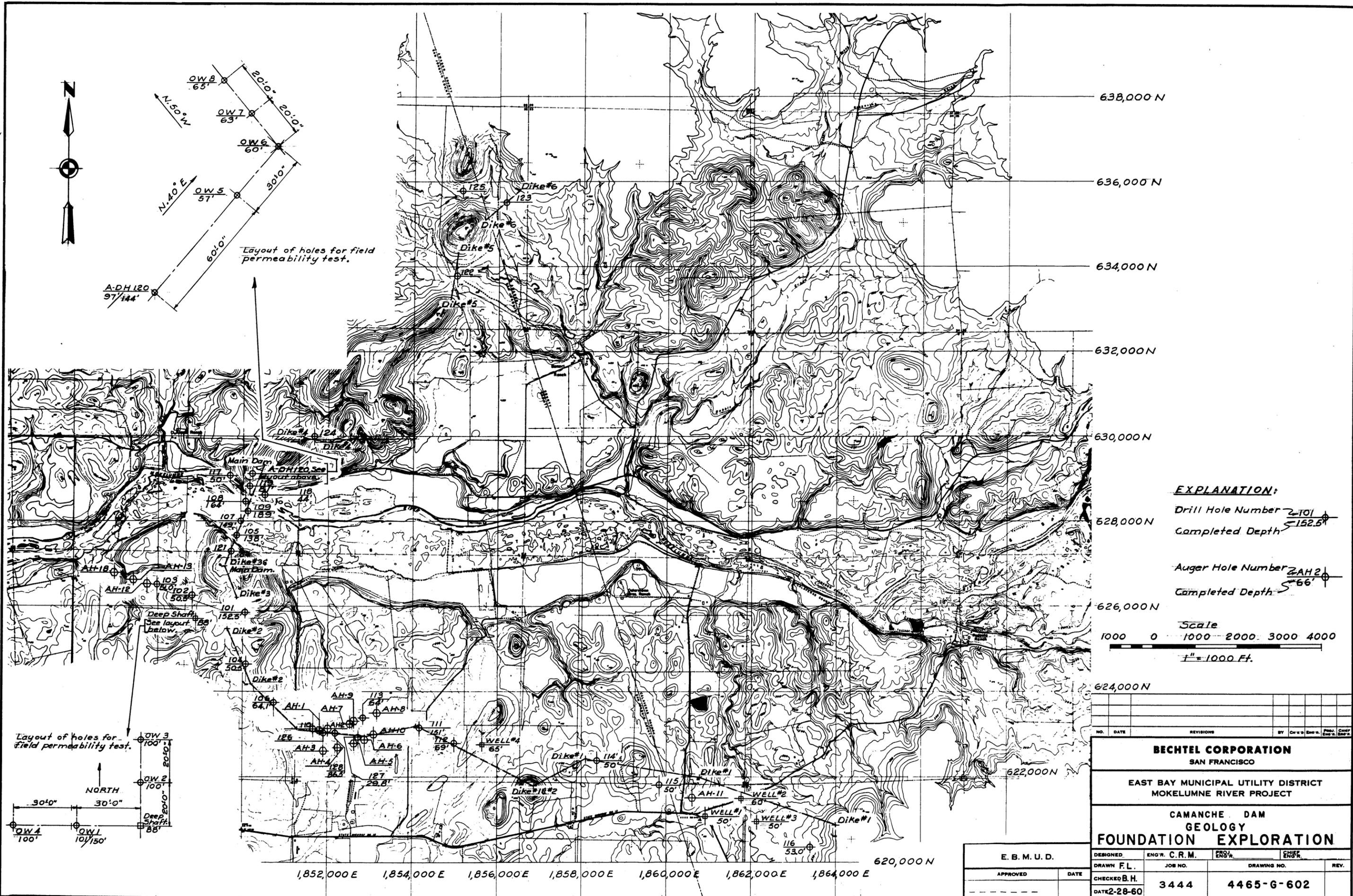
Evaluation of Test Results

The slug test method used on the right abutment is a very useful method of estimating the permeability of water bearing materials. The materials tested are of low permeability and hence the slug test method can be utilized with confidence. The attempt to conduct a non-equilibrium type of permeability test was unsuccessful in that it did not produce a quantitative result, however, it was useful in that it did establish qualitatively that the permeability was very low.

As may be noted in the table, entitled "Results of Permeability Tests, Left Abutment", the transmissibility as determined by different methods varies somewhat. This difference may be in part due to the fluctuations in the rate of pumping water into the shaft. During the critical period of the test the flow varied from a minimum of 165 gpm to a maximum of 200 gpm and averaged 197 gpm. The over-all results are remarkably uniform and substantiate that the error is minor.

The non-equilibrium method provides a means of evaluating the permeability primarily in the vicinity of the pumped well. The area at the test site on the left abutment would include the area of the shaft and surrounding observation wells. The equilibrium method provides a means of evaluating the average permeability in the entire area of influence of the pumped well.

Both the non-equilibrium and the equilibrium methods are based on the assumptions that the water bearing materials are homogeneous and isotropic and that there are no boundary condition problems. Obviously these conditions are not completely satisfied in any practical application of these testing methods. The over-all dispersion of the data obtained from the permeability tests is relatively small and the results appear to be consistent. Therefore, it is believed that the permeability results contained here are reasonably accurate and representative.



EXPLANATION:
 Drill Hole Number $\begin{matrix} \text{Z-TOI} \\ \text{---} \end{matrix}$
 Completed Depth $\begin{matrix} \text{---} \\ \text{---} \end{matrix}$
 Auger Hole Number $\begin{matrix} \text{Z-AH 2} \\ \text{---} \end{matrix}$
 Completed Depth $\begin{matrix} \text{---} \\ \text{---} \end{matrix}$
 Scale
 1000 0 1000 2000 3000 4000
 1" = 1000 Ft.

NO.	DATE	REVISIONS	BY	CHK'D	ENGR.	PROJ. CHIEF

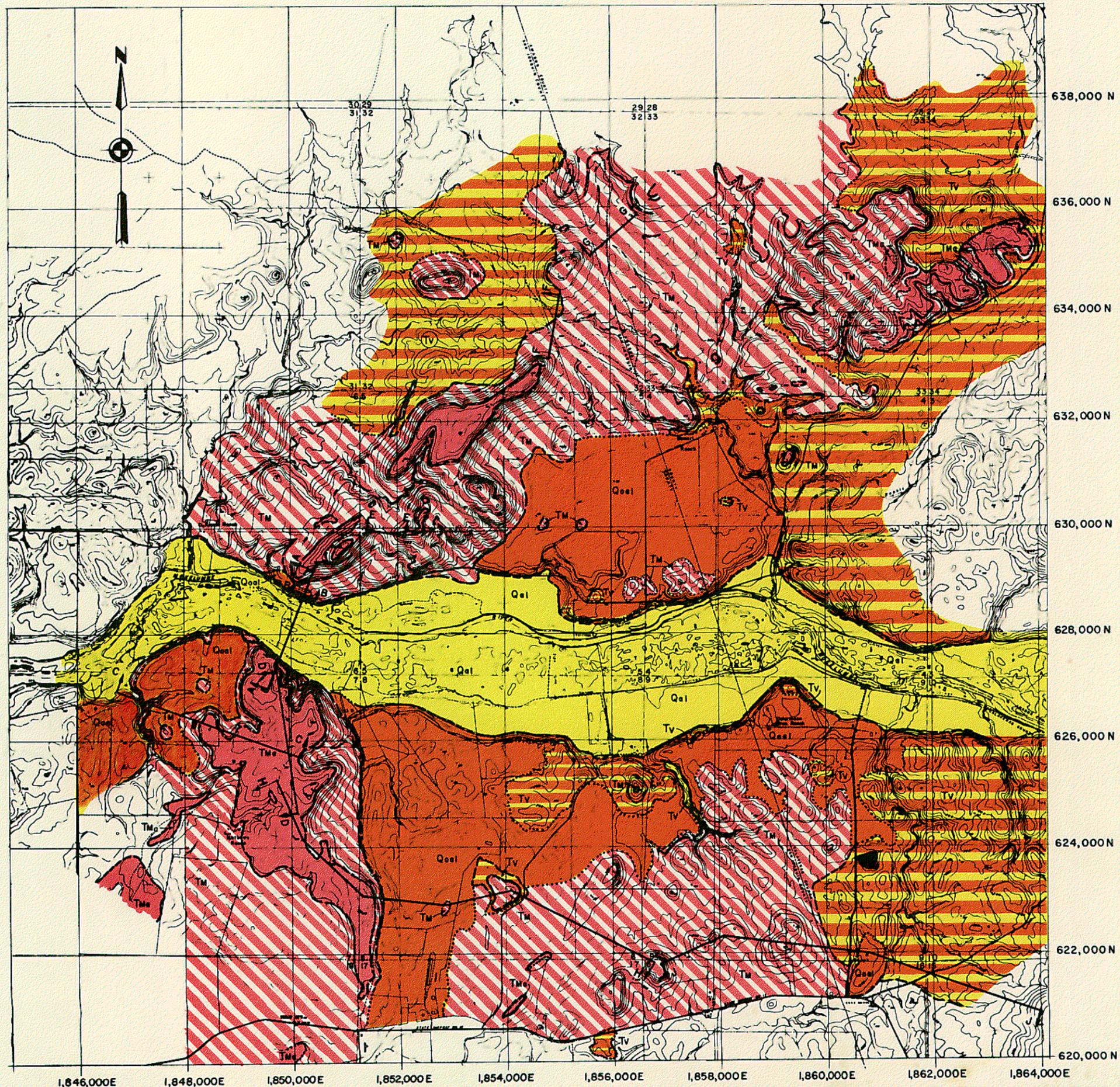
BECHTEL CORPORATION
SAN FRANCISCO

EAST BAY MUNICIPAL UTILITY DISTRICT
MOKELUMNE RIVER PROJECT

CAMANCHE DAM
GEOLOGY
FOUNDATION EXPLORATION

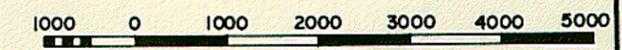
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DRAWN F.L.	JOB NO.	DRAWING NO.	REV.
CHECKED B.H.	3444	4465-G-602	
DATE 2-28-60			

E. B. M. U. D.	
APPROVED	DATE



EXPLANATION

- Qal** RECENT ALLUVIUM. Consists of river sand, gravel and silt; flood-plain deposits, and dredge tailings.
- Qoa** OLDER ALLUVIUM. Pleistocene river deposits of quartzose sand, gravel and silt. Unconsolidated to semi-indurated.
- Tm** MEHRTEN FORMATION. Mio-Pliocene fluvialite deposits of andesitic conglomerates, sandstones and siltstones and claystones (Tm) with interspersed volcanic mudflows of andesitic detritus.(Tme)
- Tv** VALLEY SPRINGS. Miocene deposits of rhyolitic tuffs, tuffaceous siltstones, claystones and sandstones high in quartz. Occasional conglomerate beds of quartz and metamorphic rocks. Locally high in pumice.
- Geologic Contact
- Inferred Contact
- Concealed Contact
- Geologic Cross-Section



1 IN. = 1,000 FEET
 CONTOUR INTERVAL 10 FEET
 DATUM IS MEAN SEA LEVEL
 2000 FOOT GRID IS BASED ON
 THE CALIFORNIA STATE PLANE COORDINATE SYSTEM
 (ZONE III)

NO.	DATE	REVISIONS	BY	CHK'D	ENGR.	PROJ. CHIEF

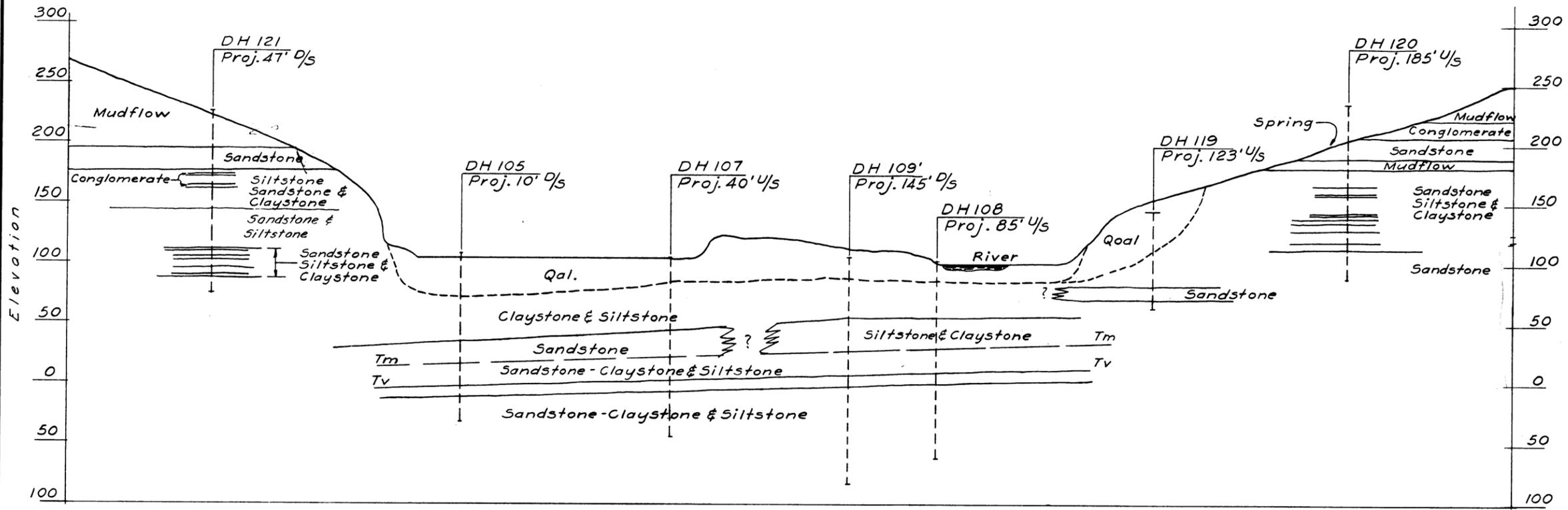
BECHTEL CORPORATION
SAN FRANCISCO

EAST BAY MUNICIPAL UTILITY DISTRICT
MOKELUMNE RIVER PROJECT

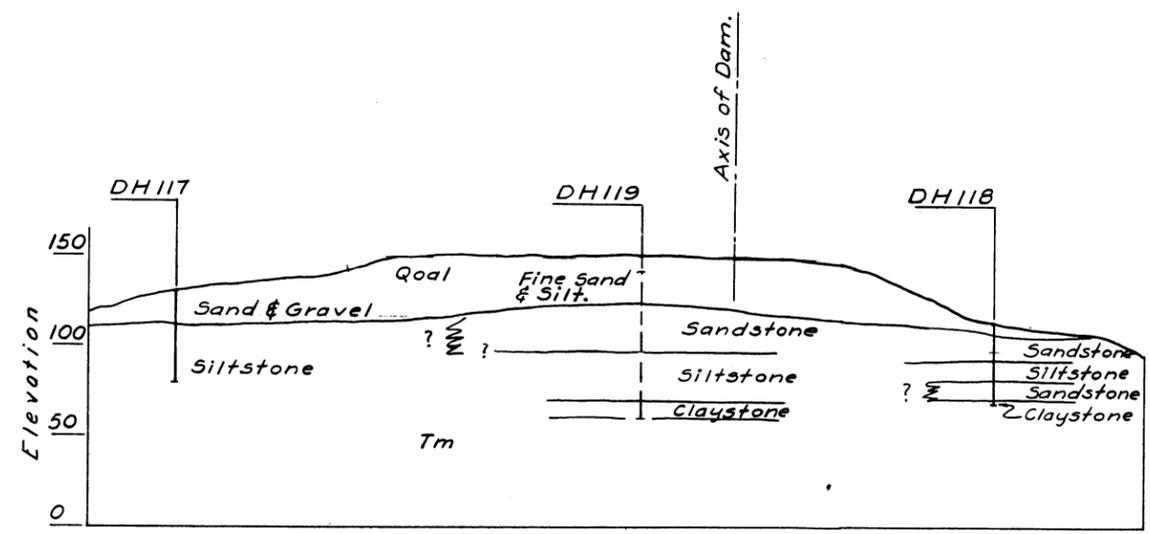
CAMANCHE DAM
GEOLOGY
GEOLOGIC MAP

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DATE 2-24-61			

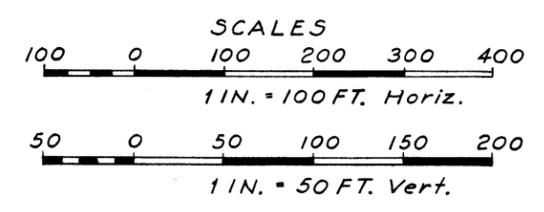
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APPROVED	DATE



SECTION A-A

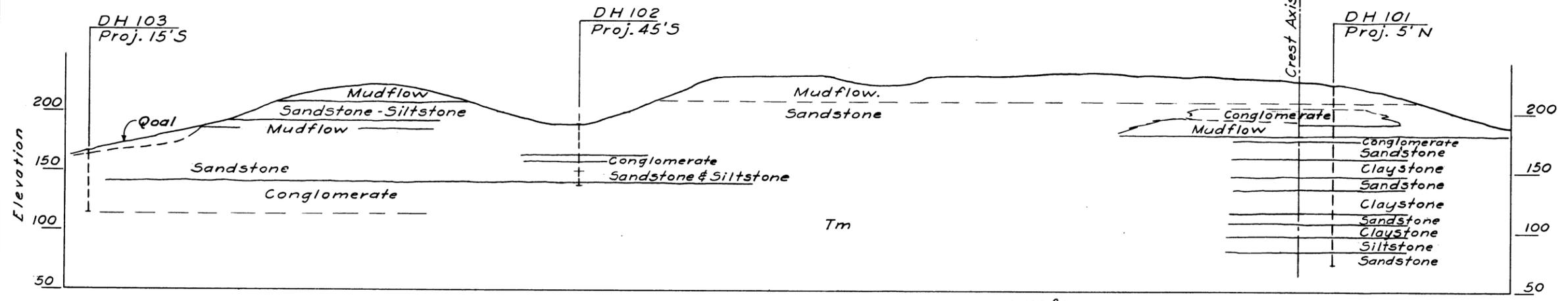


SECTION B-B

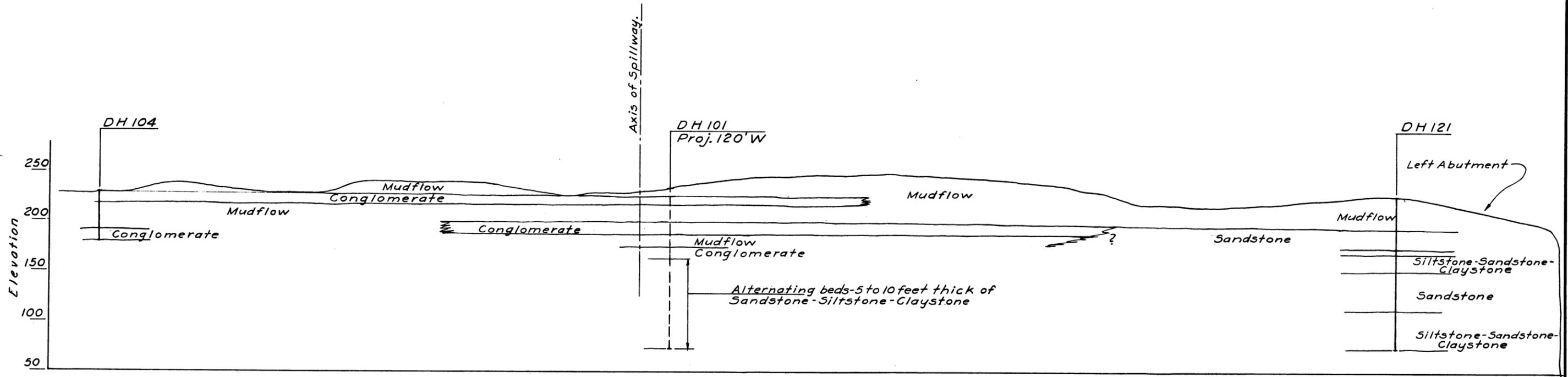


Note: For location of Geologic Sections & Legend refer to Plate II

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BECHTEL CORPORATION SAN FRANCISCO						
EAST BAY MUNICIPAL UTILITY DISTRICT MOKELUMNE RIVER PROJECT						
CAMANCHE DAM GEOLOGY GEOLOGIC SECTIONS, A-A & B-B						
E. B. M. U. D.		DESIGNED	ENGR. C. R. M.	ENGR.	ENGR.	
APPROVED	DATE	DRAWN F. L.	JOB NO.	DRAWING NO.	REV.	
		CHECKED B. H.	3444	4465-G-604	O	
		DATE 3-6-61				

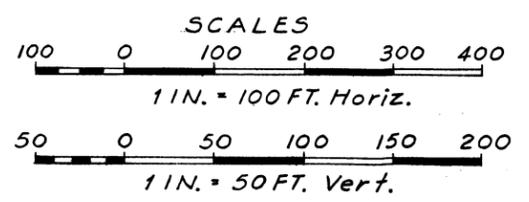


SECTION C-C
N. 70° W



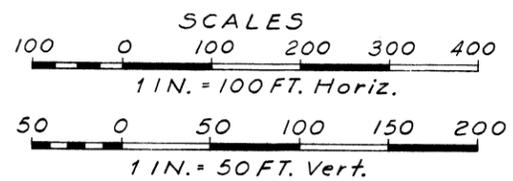
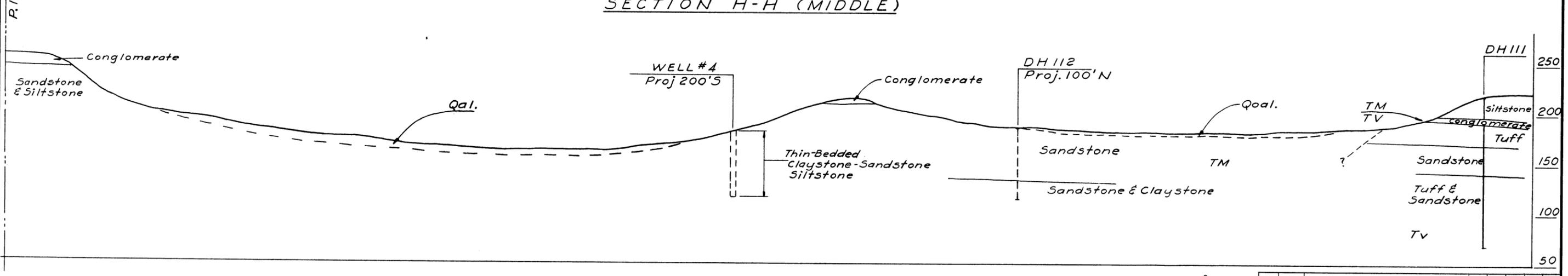
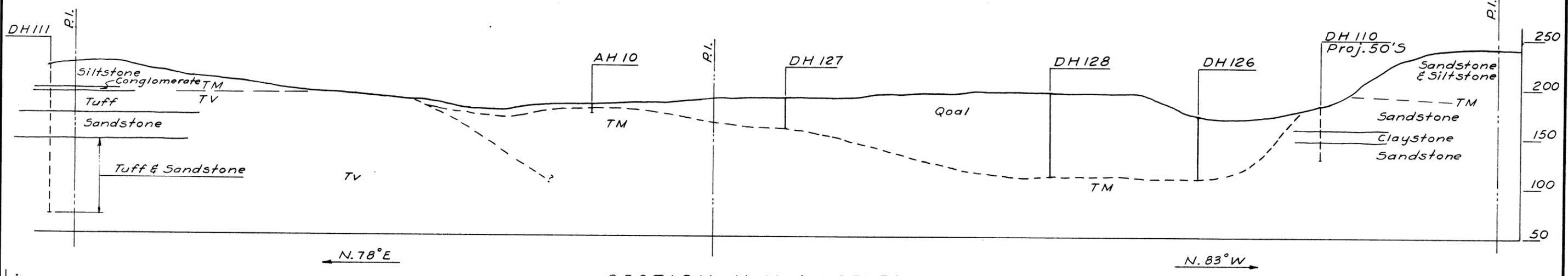
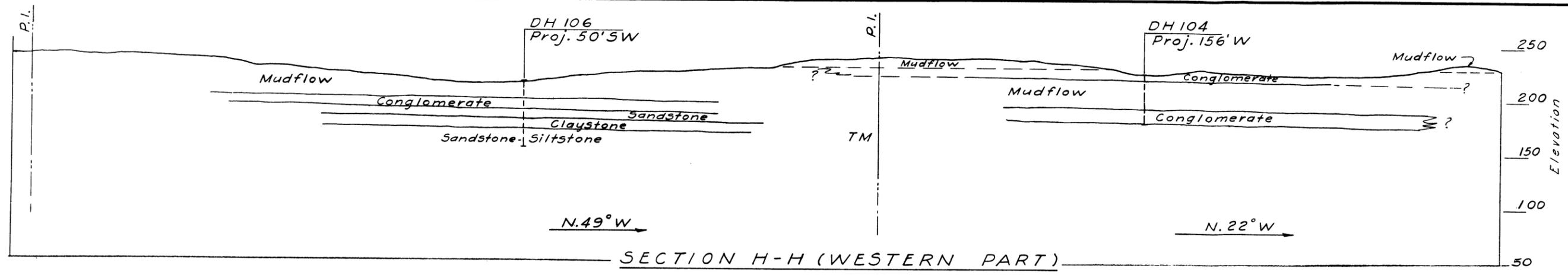
SECTION D-D
N. 7° W

Note: For location of Geologic Sections refer to Plate II.



NO.	DATE	REVISIONS	BY	CHK'D	ENGR.	Proj. Cont.
BECHTEL CORPORATION SAN FRANCISCO						
EAST BAY MUNICIPAL UTILITY DISTRICT MOKELUMNE RIVER PROJECT						
CAMANCHE DAM GEOLOGY GEOLOGIC SECTIONS, C-C & D-D						
DESIGNED		ENGR. C. R. M.		ENGR.		ENGR.
DRAWN F. L.		JOB NO.		DRAWING NO.		REV.
CHECKED B. H.		3444		4465-G-605		0
DATE 3-6-61						

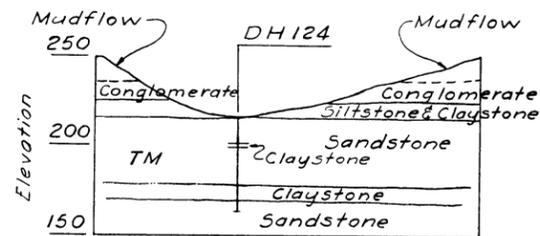
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APPROVED	DATE



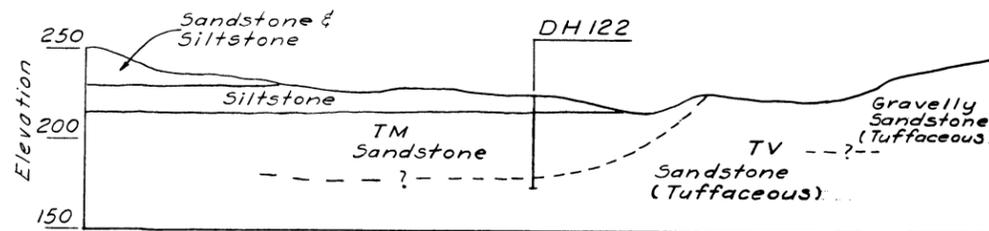
Note: For location of Geologic Sections refer to Plate II.

E. B. M. U. D.	
APPROVED	DATE
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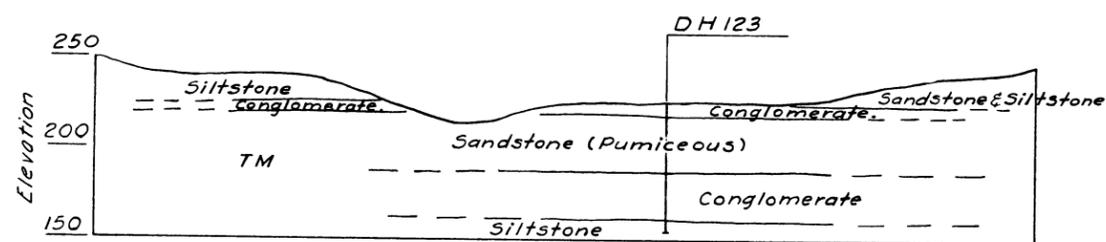
NO.	DATE	REVISIONS	BY	CHK'D	ENGR.	PROJ. CHIEF	ENGR.
BECHTEL CORPORATION SAN FRANCISCO							
EAST BAY MUNICIPAL UTILITY DISTRICT MOKELUMNE RIVER PROJECT							
CAMANCHE DAM GEOLOGY GEOLOGIC SECTION H-H							
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DRAWN F. L.	JOB NO.	DRAWING NO.		REV.			
CHECKED B. H.	3444	4465-G-606		O			
DATE 3-6-61							



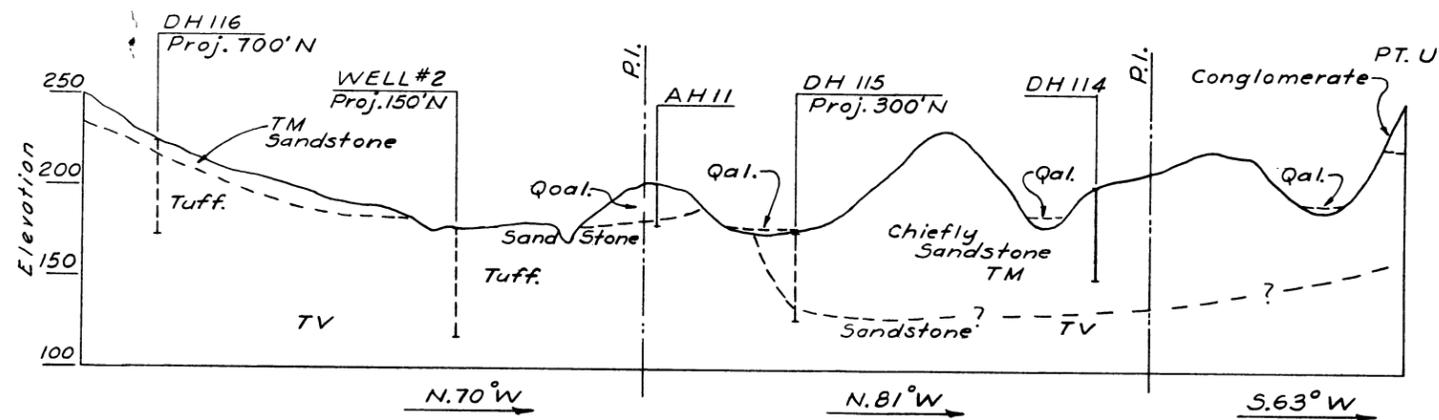
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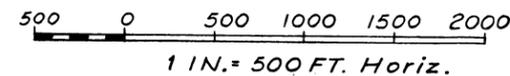
SECTION F-F



SECTION G-G

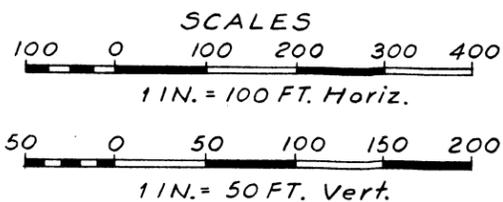


SECTION J-J



Note: For location of Geologic Sections refer to Plate II.

Sections E-E, F-F & G-G

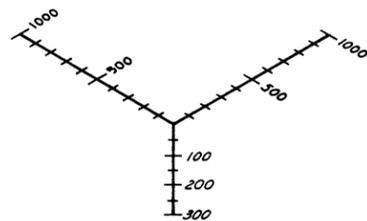
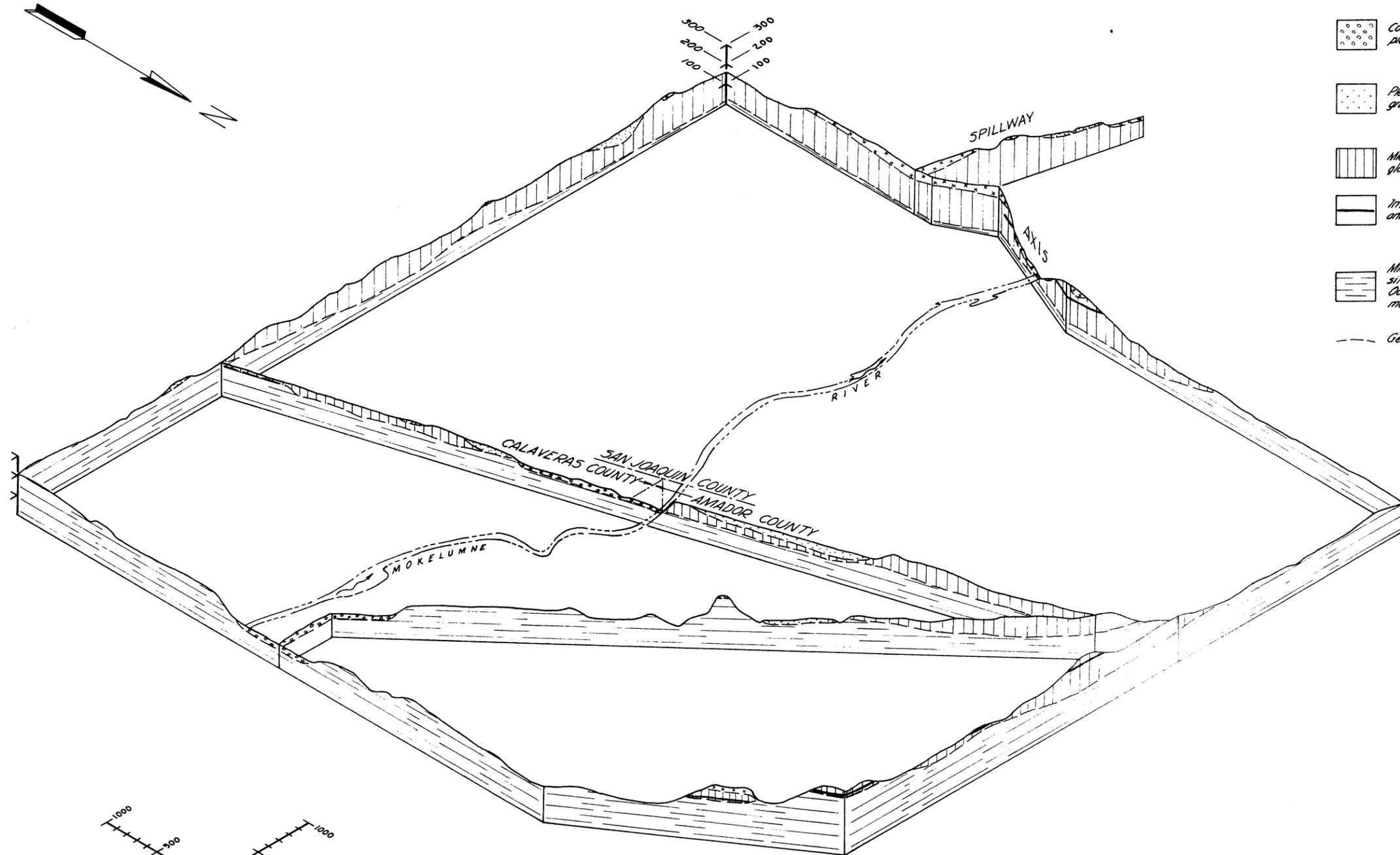


NO.	DATE	REVISIONS	BY	CHK'D	DES'N	PROJ. ENGR.	CHK'D ENGR.
BECHTEL CORPORATION SAN FRANCISCO							
EAST BAY MUNICIPAL UTILITY DISTRICT MOKELUMNE RIVER PROJECT							
CAMANCHE DAM GEOLOGY GEOLOGIC SECTIONS E-E F-F G-G J-J							
DESIGNED		ENGR. C. R. M.	ENGR.	ENGR.			
DRAWN F. L.		JOB NO.	DRAWING NO.		REV.		
CHECKED B. H.		3444	4465-G-607		O		
DATE 3-6-61							

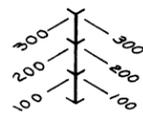
E. B. M. U. D.	
APPROVED	DATE

LEGEND

- RECENT ALLUVIUM**
 Consists of river sand, gravel, & silt; flood-plain deposits; and dredge tailings.
- OLDER ALLUVIUM**
 Pleistocene river deposits of quartzose sand, gravel, & silt. Unconsolidated to semi-indurated.
- MEHRTEN FORMATION**
 Mio-Pliocene fluvial deposits of andesitic conglomerates, sandstones, siltstones, & claystones.
- Interspersed volcanic mudflows of andesitic detritus.
- VALLEY SPRINGS FORMATION**
 Miocene deposits of rhyolitic tuff, tuffaceous siltstones, claystones, & sandstones high in quartz. Occasional conglomerate beds of quartz and metamorphic rocks. Locally high in pumice.
- Geologic Contact



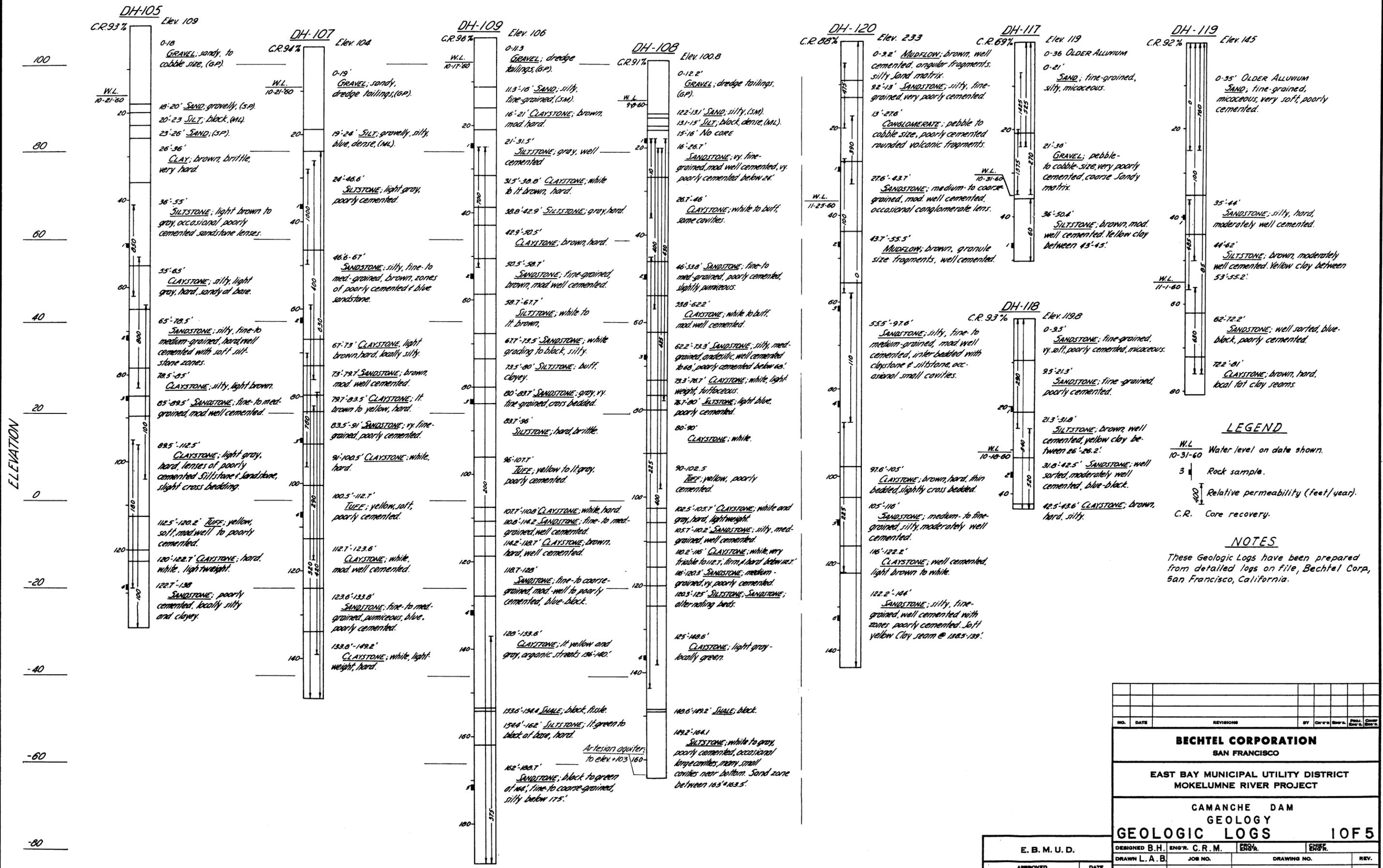
Scale in feet
Vertical Exaggeration: 1.67



Scale as shown

NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	PROJ. ENG'R	CHIEF ENG'R
BECHTEL CORPORATION SAN FRANCISCO							
EAST BAY MUNICIPAL UTILITY DISTRICT MOKELUMNE RIVER PROJECT							
CAMANCHE DAM GEOLOGY PANEL DIAGRAM							
DESIGNED D.G.C.		ENG'R. C. R. M.		ENG'R.		CHIEF	
DRAWN L. A. B.		JOB NO.		DRAWING NO.		REV.	
CHECKED D. G. C.		3444		4465-G-608		0	
DATE 3-6-61							

E. B. M. U. D.	
APPROVED	DATE



LEGEND

W.L. 10-31-60 Water level on date shown.

3 Rock sample.

Relative permeability (feet/year).

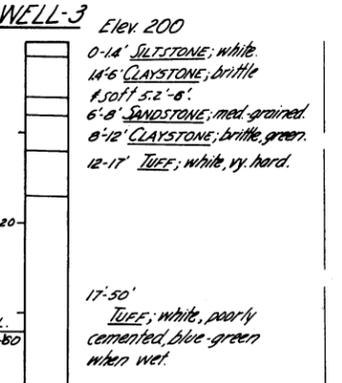
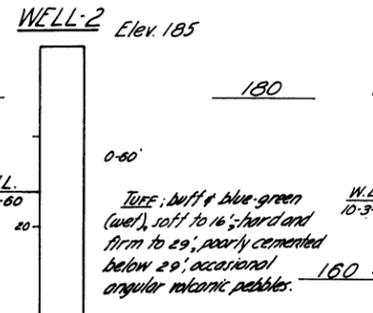
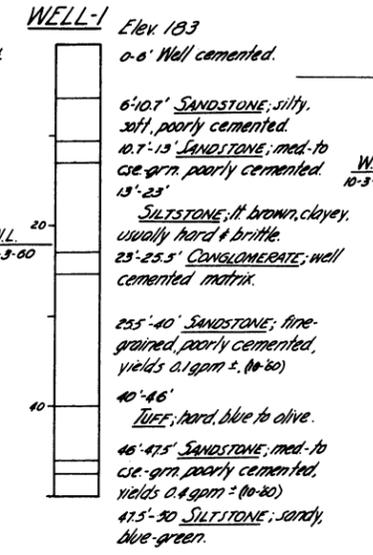
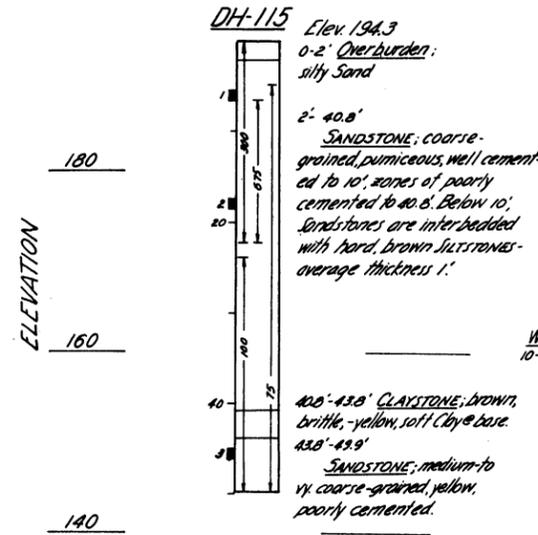
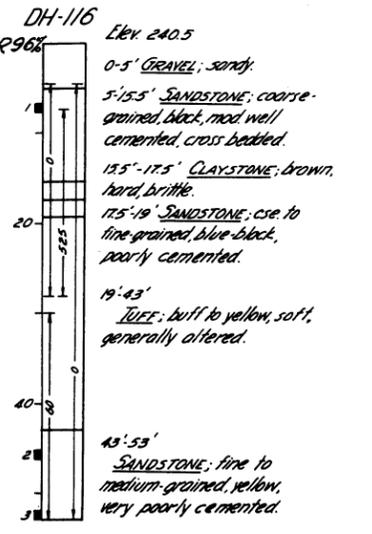
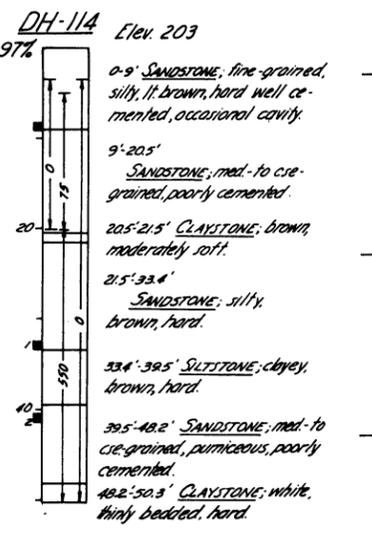
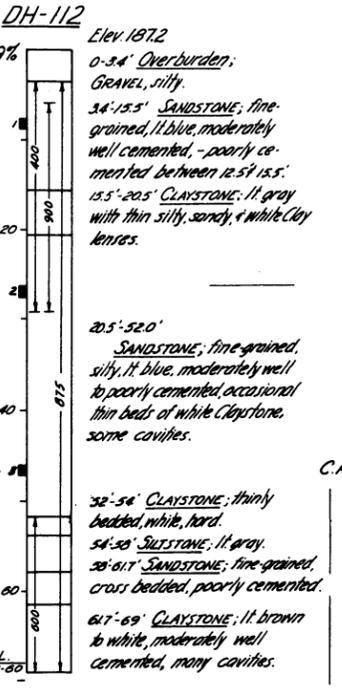
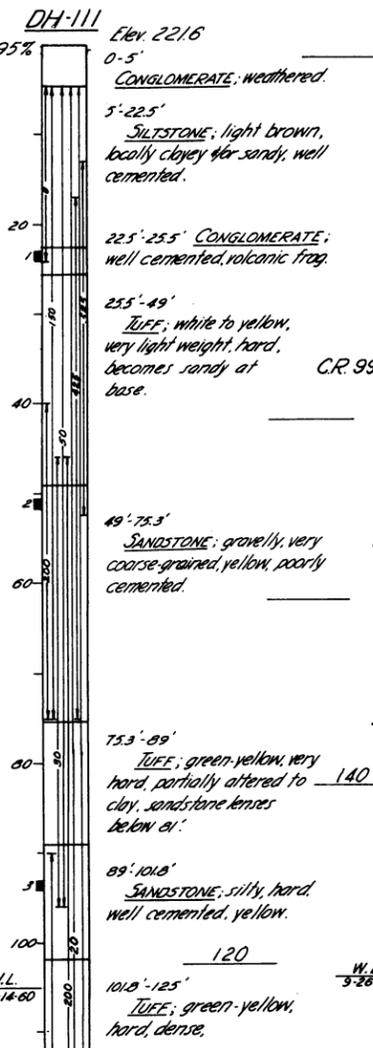
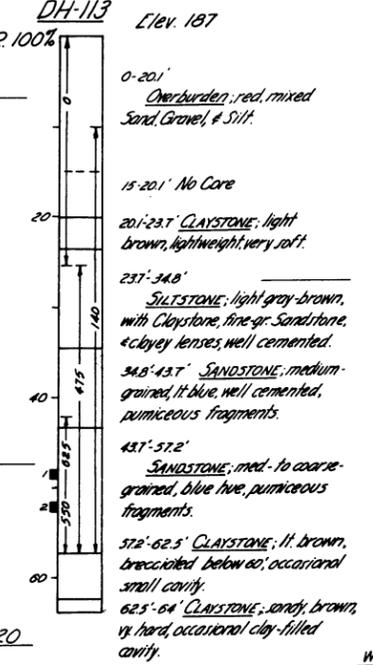
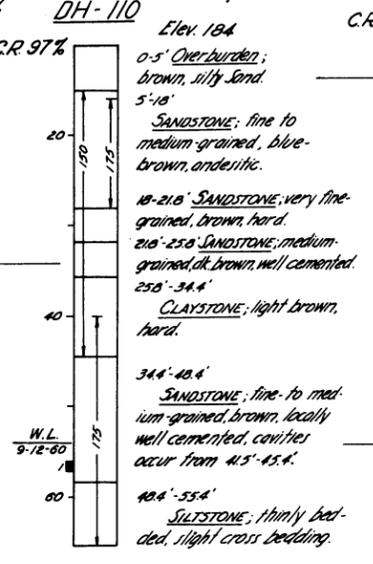
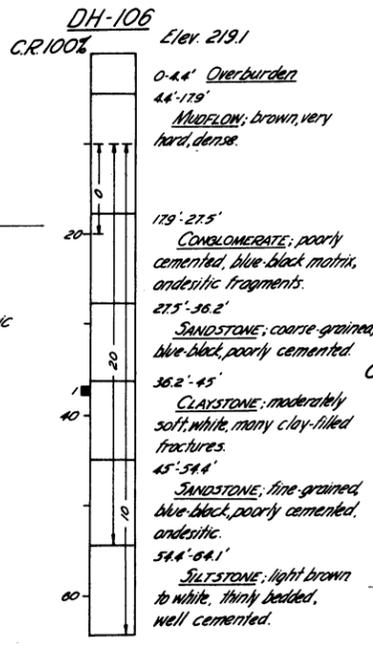
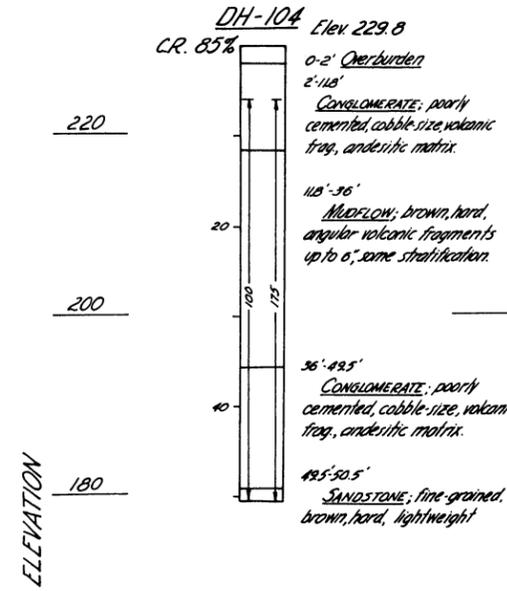
C.R. Core recovery.

NOTES

These Geologic Logs have been prepared from detailed logs on file, Bechtel Corp, San Francisco, California.

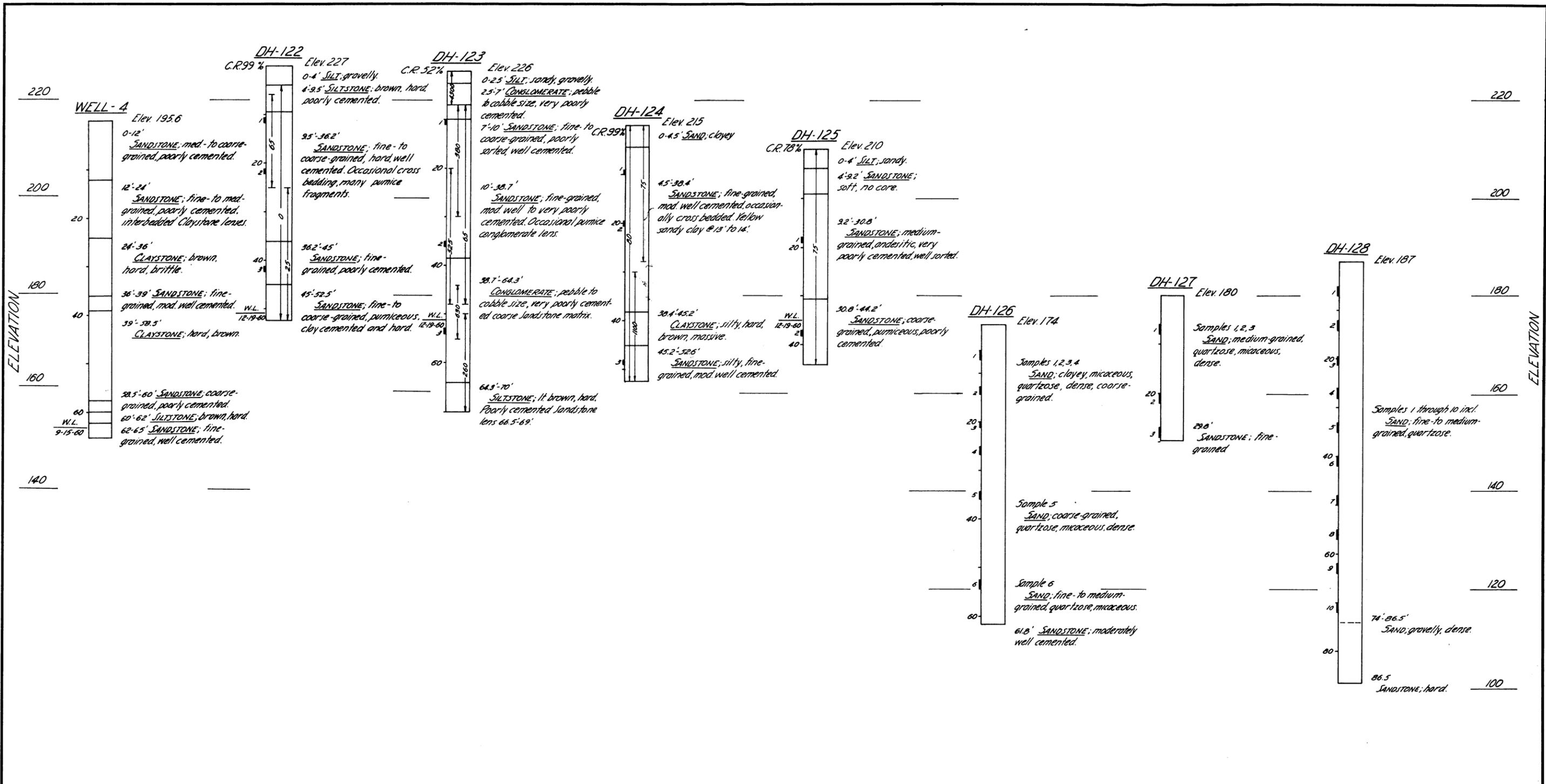
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EAST BAY MUNICIPAL UTILITY DISTRICT MOKELUMNE RIVER PROJECT				
CAMANCHE DAM GEOLOGY GEOLOGIC LOGS 10F5				
DESIGNED B.H.	ENGR. C.R.M.	ENR.	ENR.	ENR.
DRAWN L.A.B.	JOB NO. 3444	DRAWING NO. 4465-G-609		REV. 0
CHECKED B.H.	DATE 3-7-61			

E. B. M. U. D.	
APPROVED	DATE
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NOTE
Refer to Plate VIII for Legend and Notes.

BECHTEL CORPORATION SAN FRANCISCO				
EAST BAY MUNICIPAL UTILITY DISTRICT MOKELUMNE RIVER PROJECT				
CAMANCHE DAM GEOLOGY				
GEOLOGIC LOGS				2 OF 5
DESIGNED	B. H.	ENGR. C. R. M.	ENR'S	ENR'S
DRAWN	LAB	JOB NO.	DRAWING NO.	REV.
CHECKED	B. H.	3444	4465-G-610	0
DATE	3-7-61			



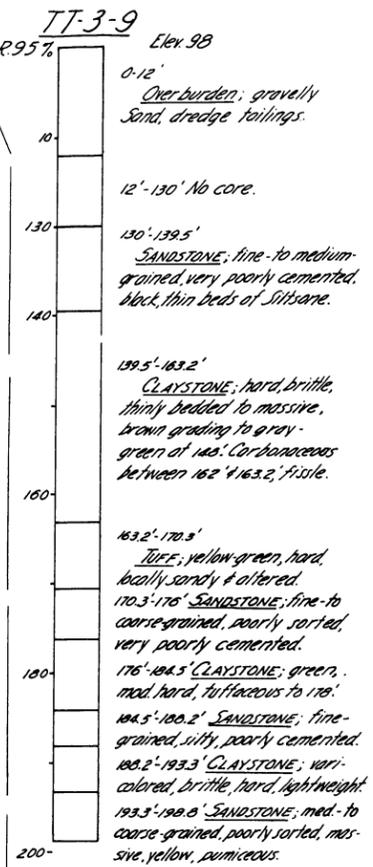
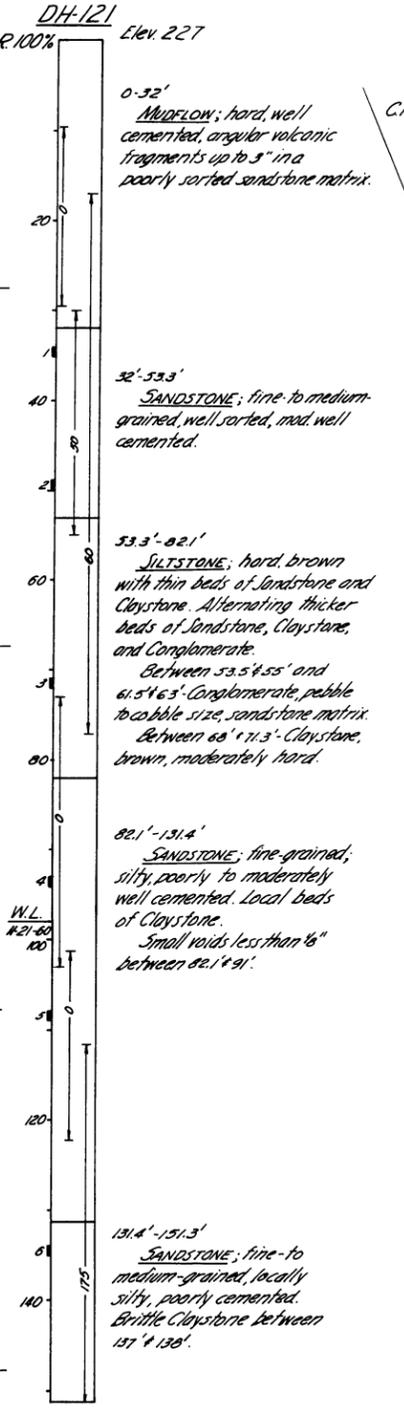
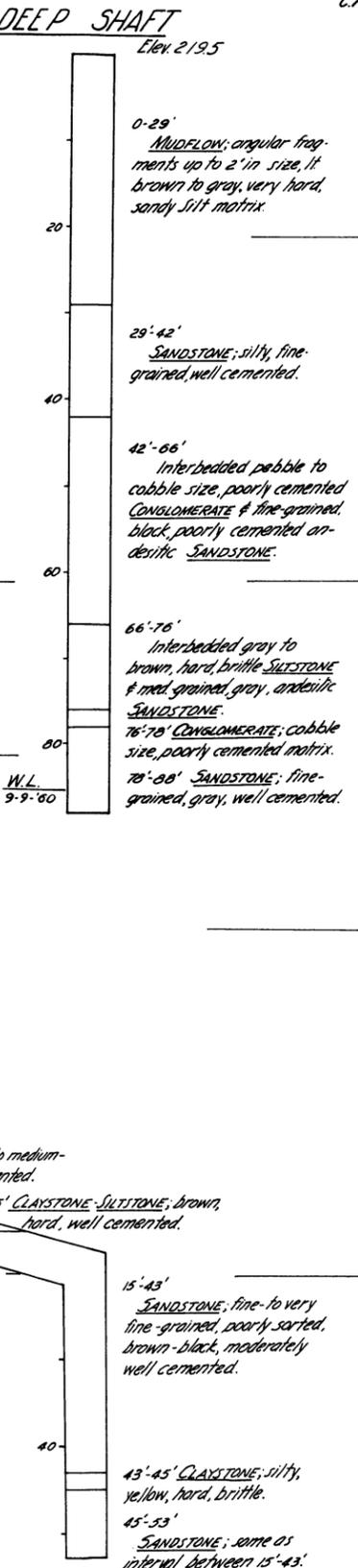
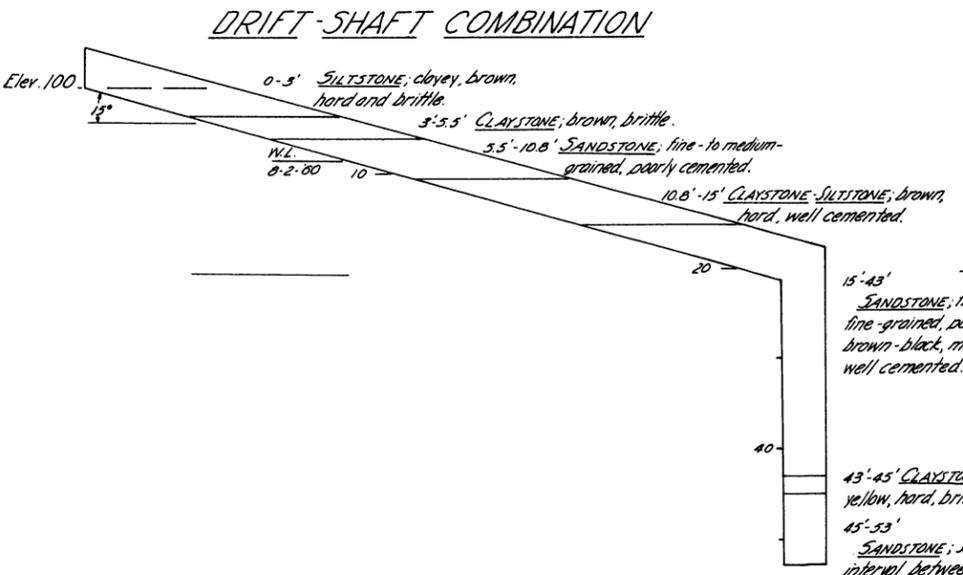
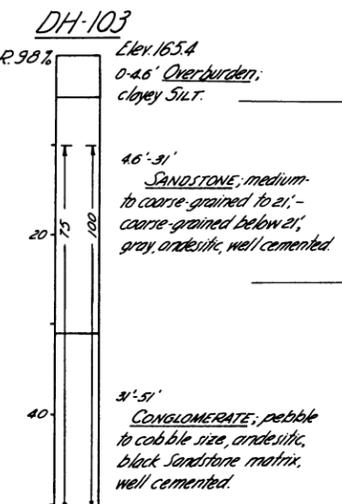
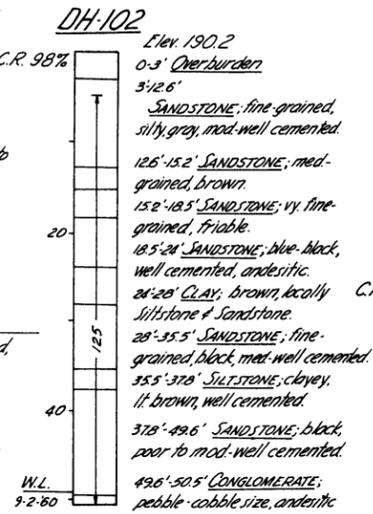
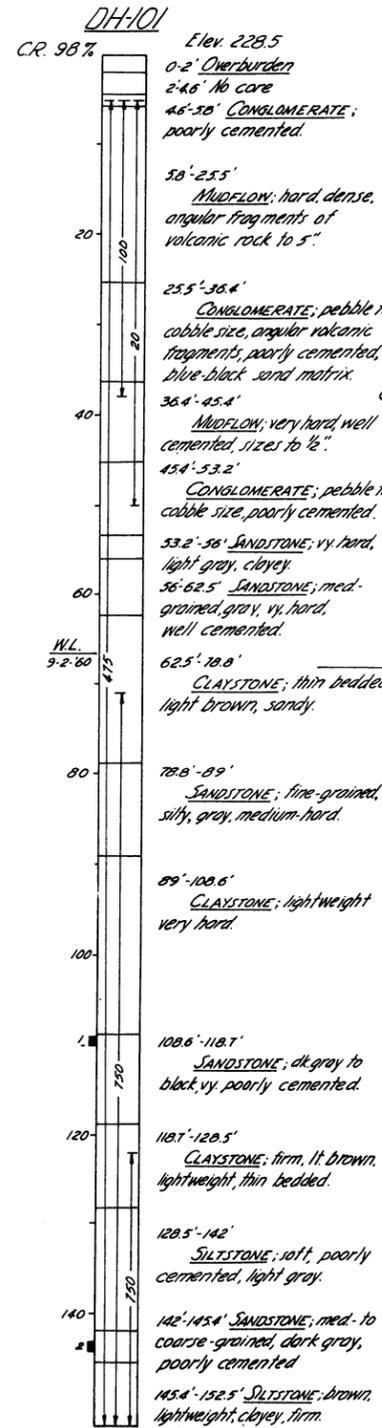
NOTE
 Refer to Plate VIII for Legend and Notes.

NO.	DATE	REVISIONS	BY	CHK'D	ENGR.	PROJ. CHIEF
BECHTEL CORPORATION SAN FRANCISCO						
EAST BAY MUNICIPAL UTILITY DISTRICT MOKELUMNE RIVER PROJECT						
CAMANCHE DAM GEOLOGY GEOLOGIC LOGS 3 OF 5						
DESIGNED B. H.		ENGR. C. R. M.		ENGR.		ENGR.
DRAWN L. A. B.		JOB NO.		DRAWING NO.		REV.
CHECKED B. H.		3444		4465-G-611		0
DATE 3-7-61						

E. B. M. U. D.	
APPROVED	DATE

ELEVATION

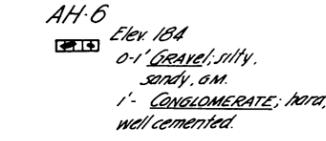
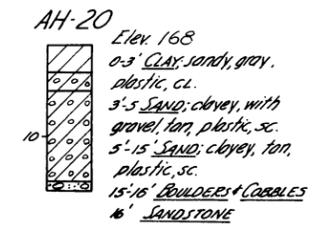
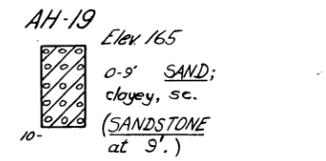
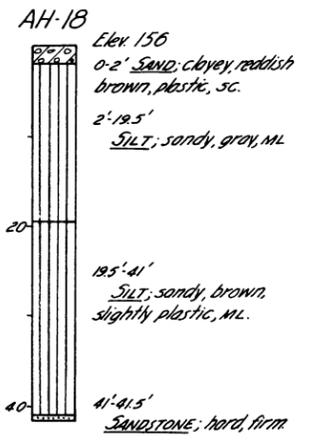
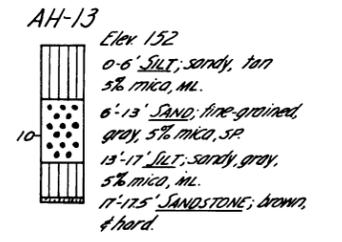
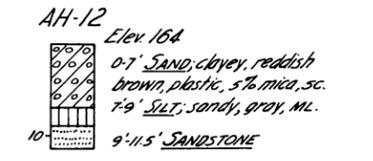
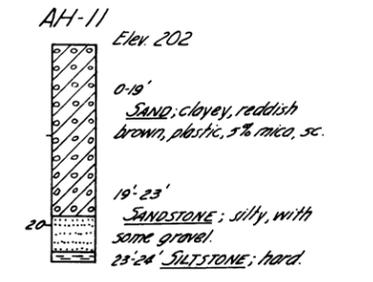
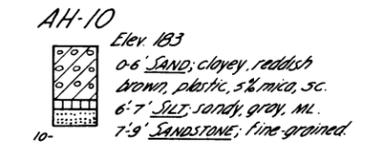
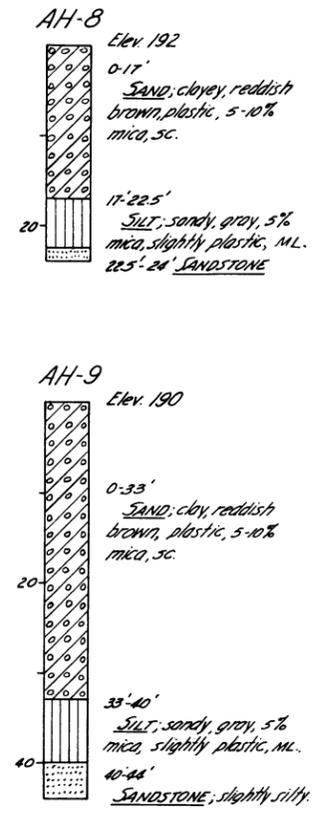
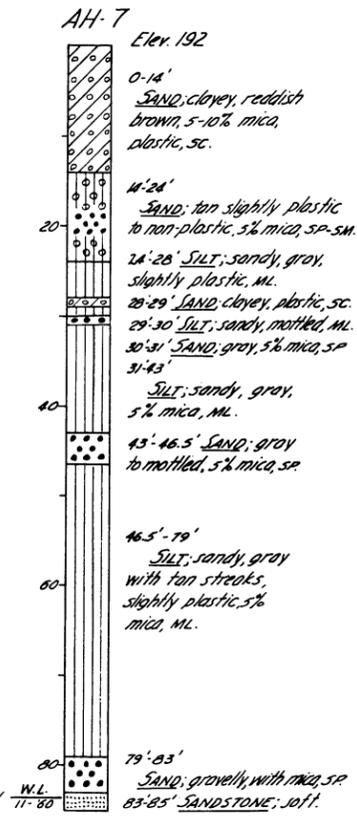
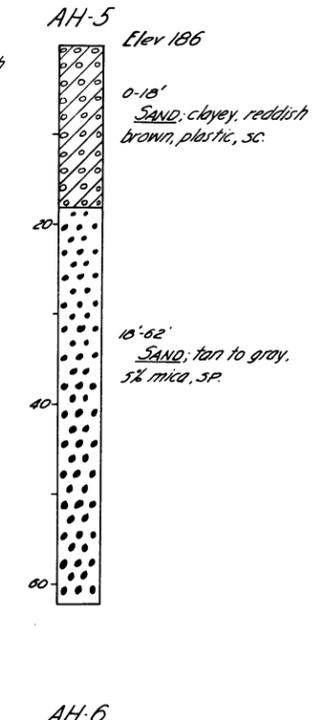
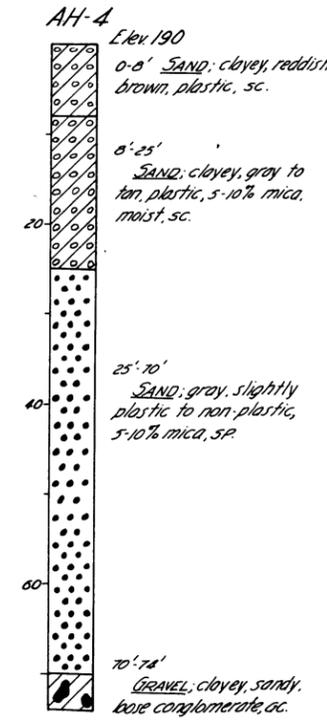
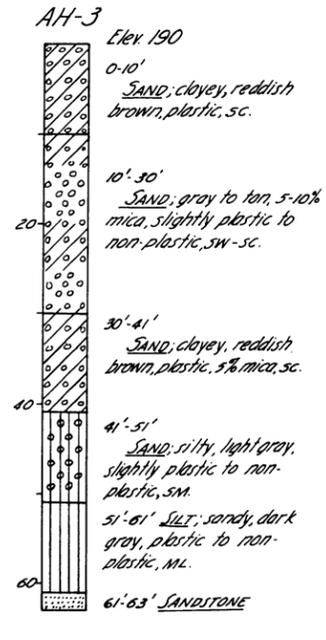
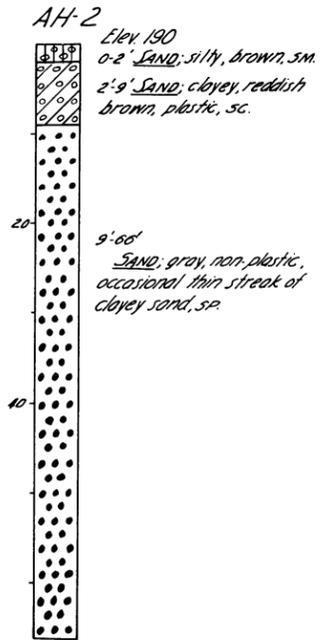
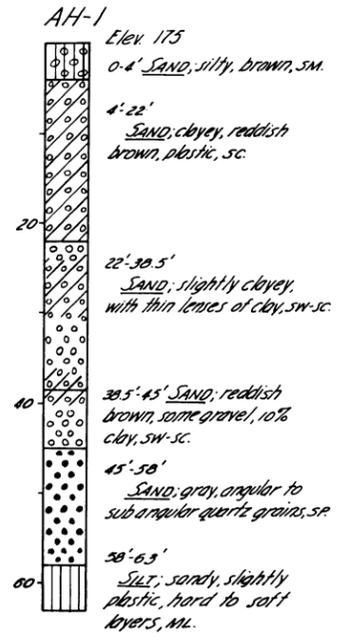
220
200
180
160
140
120
100
80



NOTE
Refer to Plate VIII for Legend and Notes.

NO. DATE					REVISIONS					BY CH'G'D. ENGR. PROJ. CHIEF ENGR. ENGR.				
BECHTEL CORPORATION SAN FRANCISCO														
EAST BAY MUNICIPAL UTILITY DISTRICT MOKELUMNE RIVER PROJECT														
CAMANCHE DAM GEOLOGY GEOLOGIC LOGS 4 OF 5														
DESIGNED B. H.			ENGR. C. R. M.			ENGR. A.			ENGR.					
DRAWN L. A. B.			JOB NO.			DRAWING NO.			REV.					
CHECKED B. H.			3444			4465-G-612			0					
DATE 3-7-61														

E. B. M. U. D.	
APPROVED	DATE
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NOTE
1. Refer to Plate VIII for Legend and Notes.
2. Symbols and classification based on Unified Soils Classification system.

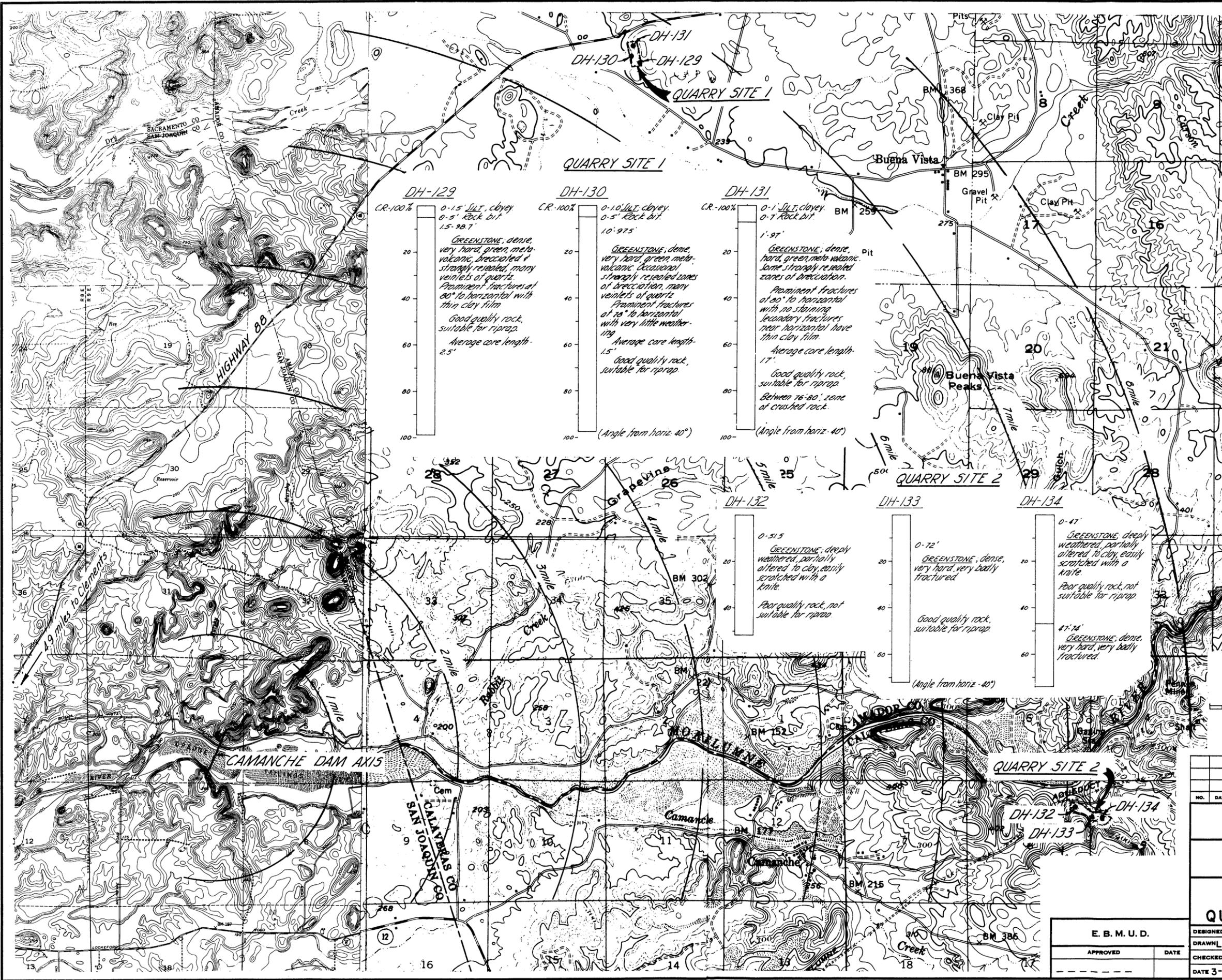
E. B. M. U. D.		DESIGNED	ENGR. C. R. M.	ERS%	ENGR.
APPROVED	DATE	DRAWN	JOB NO.	DRAWING NO.	REV.
		L.B./D.C.R.	3444	4465-G-613	0
		CHECKED			
		DATE	3-7-61		

BECHTEL CORPORATION
SAN FRANCISCO

EAST BAY MUNICIPAL UTILITY DISTRICT
MOKELUMNE RIVER PROJECT

CAMANCHE DAM
GEOLOGY

GEOLOGIC LOGS 5 OF 5



DH-129
 CR-100%
 0-1.5' SILT, clayey
 0-5' Rock bit
 1.5-98.7'
 GREENSTONE, dense, very hard, green, meta-volcanic, brecciated & strongly veined, many veinlets of quartz. Prominent fractures at 80° to horizontal with thin clay film.
 Good quality rock, suitable for riprap.
 Average core length - 2.5'

DH-130
 CR-100%
 0-1.0' SILT, clayey
 0-5' Rock bit
 10-97.5'
 GREENSTONE, dense, very hard, green, meta-volcanic. Occasional strongly veined zones of brecciation, many veinlets of quartz. Prominent fractures at 70° to horizontal with very little weathering.
 Average core length - 1.5'
 Good quality rock, suitable for riprap.
 (Angle from horiz. 40°)

DH-131
 CR-100%
 0-1' SILT, clayey
 0-7' Rock bit
 1-97'
 GREENSTONE, dense, hard, green, meta-volcanic. Some strongly veined zones of brecciation.
 Prominent fractures at 80° to horizontal with no staining. Secondary fractures near horizontal have thin clay film.
 Average core length - 17'
 Good quality rock, suitable for riprap.
 Between 76-80°, zone of crushed rock.
 (Angle from horiz. 40°)

DH-132
 0-51.5'
 GREENSTONE, deeply weathered, partially altered to clay, easily scratched with a knife.
 Poor quality rock, not suitable for riprap.

DH-133
 0-72'
 GREENSTONE, dense, very hard, very badly fractured.
 Good quality rock, suitable for riprap.
 (Angle from horiz. 40°)

DH-134
 0-47'
 GREENSTONE, deeply weathered, partially altered to clay, easily scratched with a knife.
 Poor quality rock, not suitable for riprap.
 47-74'
 GREENSTONE, dense, very hard, very badly fractured.

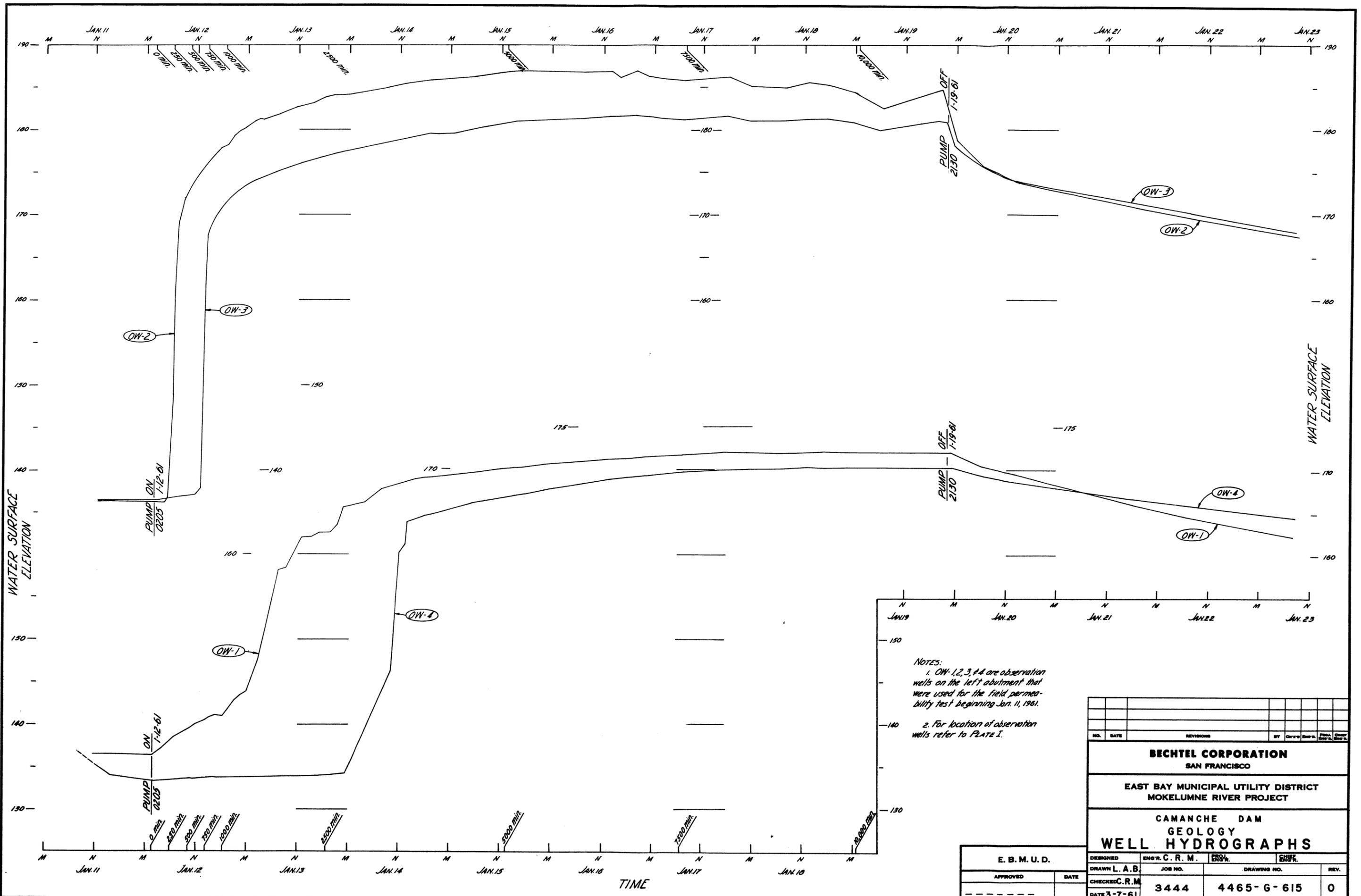
LEGEND

- Quarry Site
- Drill Hole



NO.				DATE				REVISIONS				BY		CHK'D		ENGR.		PROJ. CHIEF	
BECHTEL CORPORATION SAN FRANCISCO																			
EAST BAY MUNICIPAL UTILITY DISTRICT MOKELUMNE RIVER PROJECT																			
CAMANCHE DAM GEOLOGY QUARRY EXPLORATION																			
DESIGNED				ENGR. C. R. M.				ENGR.				ENGR.							
DRAWN A. B.				JOB NO.				DRAWING NO.				REV.							
CHECKED C. R. M.				3444				4465-G-614				0							
DATE 3-8-61																			

E. B. M. U. D.	
APPROVED	DATE
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JAN 19 JAN 20 JAN 21 JAN 22 JAN 23

NOTES:
 1. OW-1, 2, 3, & 4 are observation wells on the left abutment that were used for the field permeability test beginning Jan. 11, 1961.
 2. For location of observation wells refer to PLATE I.

BECHTEL CORPORATION SAN FRANCISCO			
EAST BAY MUNICIPAL UTILITY DISTRICT MOKELUMNE RIVER PROJECT			
CAMANCHE DAM GEOLOGY WELL HYDROGRAPHS			
DESIGNED	ENG'R. C. R. M.	ENG'R.	ENGR.
DRAWN L. A. B.	JOB NO.	DRAWING NO.	REV.
CHECKED C. R. M.	3444	4465-G-615	0
DATE 3-7-61			

E. B. M. U. D.	
APPROVED	DATE
