White Pine Power Project

GROUNDWATER INVESTIGATION
PHASE 3

TECHNICAL REPORT

APPENDICES

EXHIBIT 40
FOR:
☐ STATE OF NEVADA
☐ PROTESTANT
☒ APPLICANT
☐ ________ OTHER
DATE 8-17-83

GROUNDWATER INVESTIGATION
PHASE 3

APPENDICES

Technical Report

for the

WHITE PINE POWER PROJECT

Prepared For

Los Angeles Department of Water and Power

LEEDS, HILL AND JEWETT, INC
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May 1983

APPENDIX A

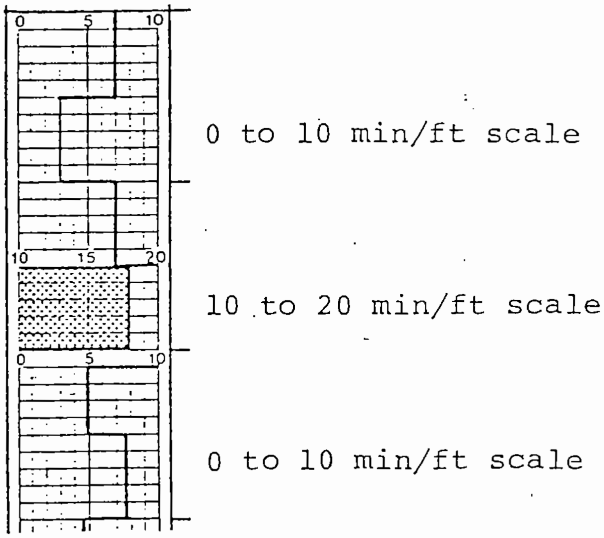
List of Abbreviations

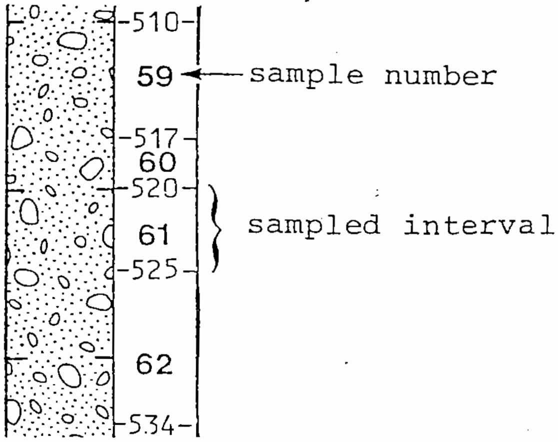
afy	acre-feet per year
BLM	Bureau of Land Management
cfs	cubic feet per second
^{o}F	degrees Fahrenheit
DTW	depth to water (from ground surface)
DWR	Division of Water Resources
EDI	Environmental Dynamics, Inc.
gpd/ft	gallons per day per foot
gpm	gallons per minute
gpm/ft	gallons per minute per foot
HLA	Harding-Lawson Associates
hp	horsepower
LADWP	Department of Water and Power of the City of Los Angeles
LEEDSHILL	Leeds, Hill and Jewett
mg/l	milligrams per liter
msl	mean sea level
NDCNR	Nevada Department of Conservation and Natural Resources
ppm	parts per million
s	drawdown, from static water level to pumping water level, in feet
S	coefficient of storage (dimensionless, ft^3/ft^3)
SC	specific conductivity
SCS	U.S. Soil Conservation Service

sq. mi.	square miles
t	time
T	coefficient of transmissivity (gpd/ft)
TDS	Total Dissolved Solids
USGS	U.S. Geological Survey
VES	vertical electric soundings
WPPP	White Pine Power Project
WRB	Water Resource Bulletin
WSP	Water Supply Paper

APPENDIX B

KEY TO FIELD DRILLING LOGS



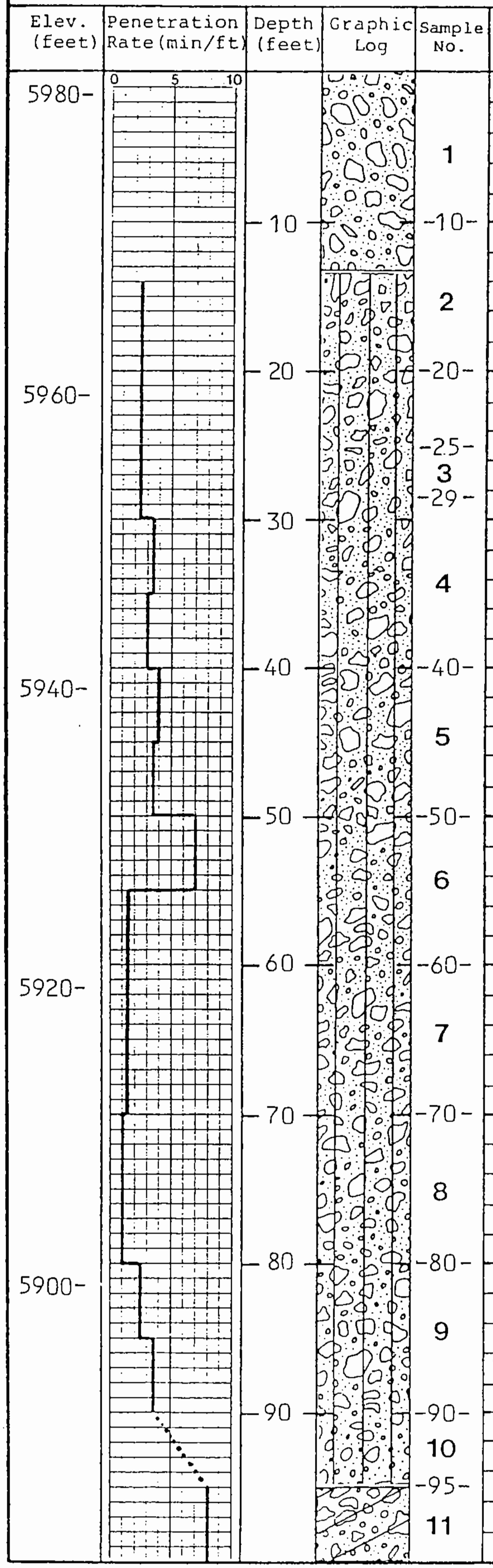


Penetration rate scale adjustment

Samples classified in accordance with the Unified Soil Classification System.

FIELD DRILLING LOG

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 1-A
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5981.6
Location: Steptoe Valley
Dates drilled: July 1982
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 280 Drill Rig/Mud Rotary 0 - 995 ft., 12.25" tricone bit.
Page 1 of 10



Description

Remarks

GRAVEL (GW); poorly sorted light brown silty sandy gravel with subangular rock fragments, slightly calcareous.

SILTY SAND AND GRAVEL (SM/GM); poorly sorted light brown gravelly sand, subangular, fine to coarse grains, calcareous.

(grades siltier)

(grades more gravelly)

(grades less gravelly)

(grades more gravelly)

CLAYEY GRAVEL (GC); brown clayey silty gravel, poorly sorted angular rock fragments in clay silt and sand matrix.

FIELD DRILLING LOG

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 1-A
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5981.6
Location: Steptoe Valley
Dates drilled: July 1982
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 280 Drill Rig/Mud Rotary 0 - 995 ft., 12.25" tricone bit.
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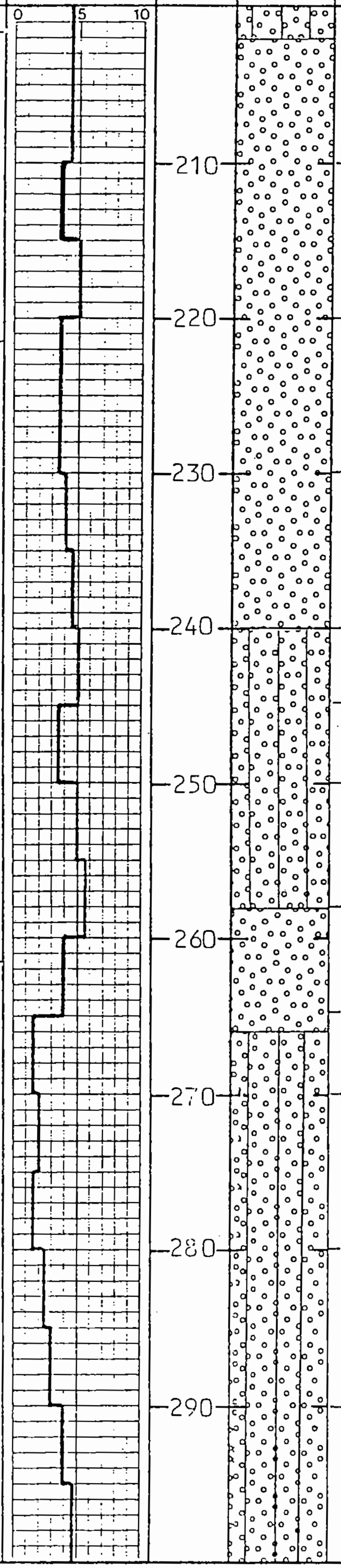

Elev. (feet)	Depth (feet)	Sample No.	Description	Remarks
5780		24	SAND (SW); poorly sorted sand, fine to coarse grains composed of chert, quartz and rock fragments.	Drilling slow and rough.
	210	25		
	220			Rough drilling.
5760		26		
	230	27	(some volcanic rock fragments included).	Drill rig chattering.
	240	28	SILTY SAND (SM); poorly sorted silty sand, very fine to coarse grained, subrounded to subangular.	
5740	245	29		
	250	30		Rough drilling.
	258	31	SAND (SW); poorly sorted sand, fine to very coarse grained, subangular, abundant chert fragments.	
5720	260			
	265	32	SILTY SAND (SM); poorly sorted silty sand, very fine to coarse grain, subangular.	
	270	33		Drills smoother.
	280	34		
5700				
	290	35		

FIELD DRILLING LOG

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 1-A
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5981.6
Location: Steptoe Valley
Dates drilled: July 1982
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 280 Drill Rig/Mud Rotary
0 - 995 ft., 12.25" tricone bit.
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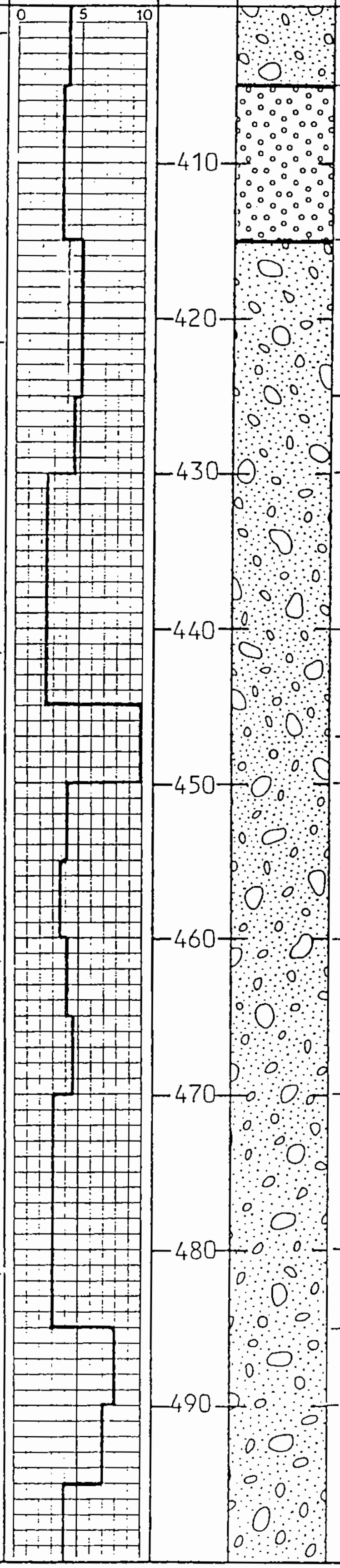

Elev. (feet)	Depth (feet)	Sample No.	Description	Remarks
5580		46	coarse to fine sand, angular to subangular quartz and rock fragment grains.	
	405	47	SAND (SW); poorly sorted sand and gravel, coarse to fine grained, subangular, rock fragments.	
	410			
	415	48	GRAVEL (GW); poorly sorted gravel and sand, angular grains, gravel 1/10" to 2/10", fine to coarse sand , clasts include olovine, feldspar, quartz and rock fragments.	
5560	420			
	425			
	430	49		Size and angularity of cuttings indicate breaking of cobbles and boulders.
5540	440	50		
	447	51		
	450	52		Angular rock frags.
5520	460	53	(grades more sandy)	
	470	54		
5500	480	55		
	485	56		
	490	57		

FIELD DRILLING LOG

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 1-A
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5981.6
Location: Steptoe Valley
Dates drilled: July 1982
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 280 Drill Rig / Mud Rotary
0 - 995 ft., 12.25" tricone bit.
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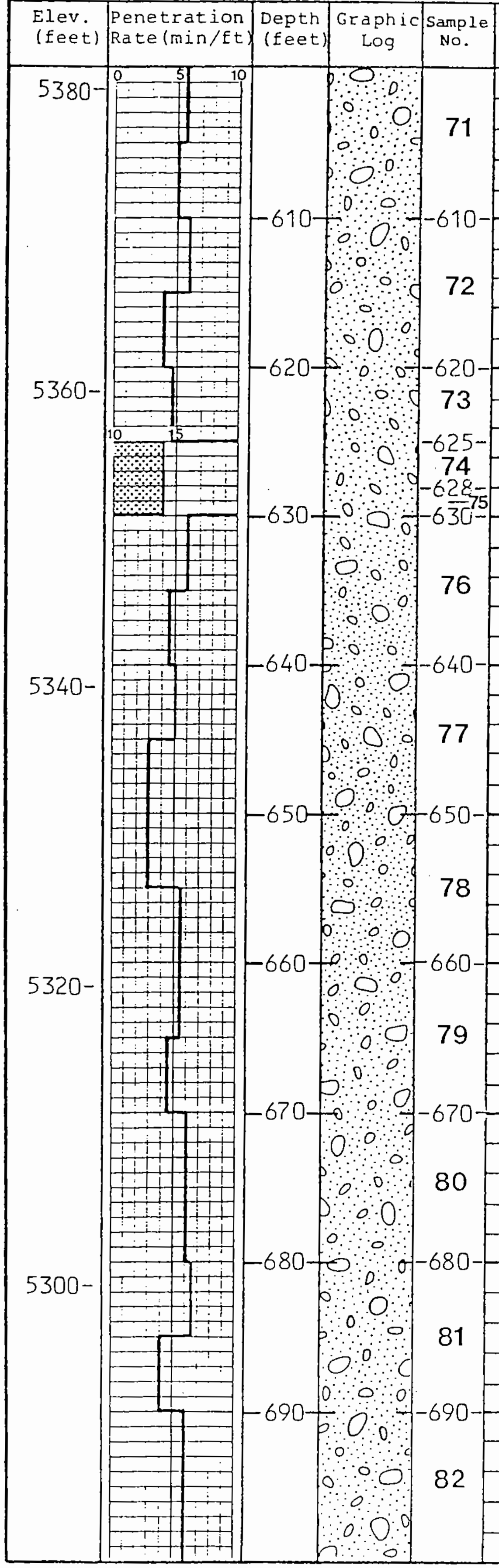

Description

GRAVEL (GW); poorly sorted gravel and sand, small to large gravel, fine to coarse sand, angular to subangular, igneous in composition.

(grades silty)

(grades sandier and very silty)

Remarks

Drill rig chattering.

Angularity of cuttings indicates breaking of cobbles and boulders.

Drill rig chattering.

FIELD DRILLING LOG

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 1-A
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5981.6
Location: Steptoe Valley
Dates drilled: July 1982
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 280 Drill Rig / Mud Rotary
0 - 995 ft., 12.25" tricone bit.
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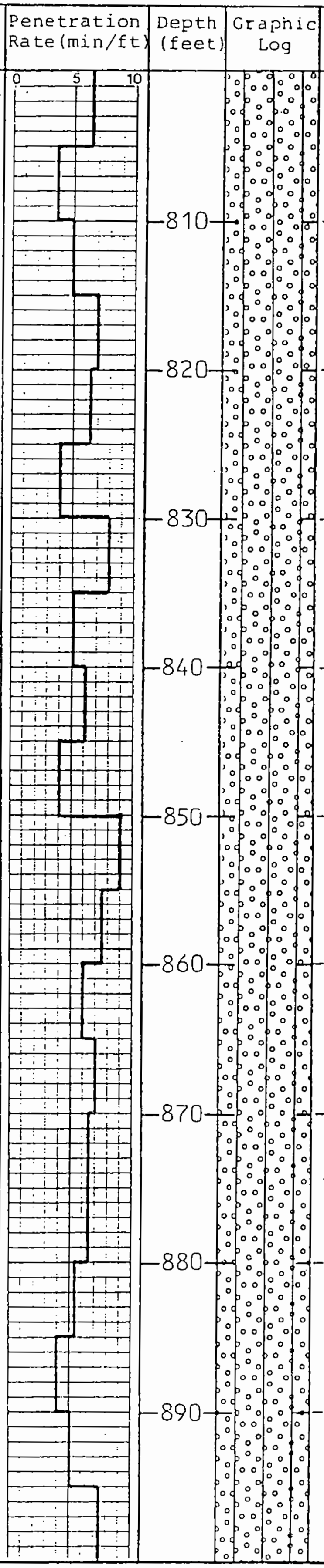
Elev. (feet)	Depth (feet)	Sample No.	Description	Remarks
5180		93	SILTY SAND (SM); brown poorly sorted silty fine to coarse sand, subangular to angular, composed of igneous rock fragments.	Drill rig chattering.
	810			
		94		
	820			
5160				
		95	(grades siltier)	
	830			
		96		
	840			
5140				
		97		
	850			
		98		Drill rig chattering.
	860			
5120				
		99		
	870			
		100		Drill rig chattering.
	880			
5100				
		101		
	890			Loud drill rig chatter.
		102		



FIELD DRILLING LOG

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 1-B
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5961.2
Location: Steptoe Valley
Dates drilled: 7·82 to 8·82
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 280 Drill Rig/Mud Rotary
0 - 50 ft., 17.5" tricone bit; 50 - 460 ft., 11" tricone bit.
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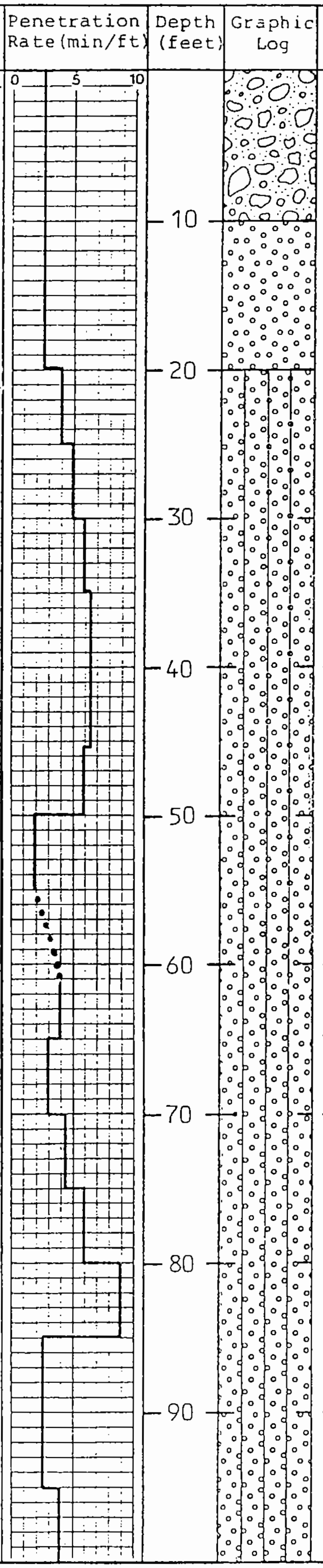

Elev. (feet)	Penetration Rate (min/ft)	Depth (feet)	Graphic Log	Sample No.	Description	Remarks
5960				1	GRAVEL (GW); poorly sorted silty sandy gravel, 1/10" to 3/10", subrounded clasts composed primarily of sandstone & limestone, calcareous.	
		10		-10- 2	SAND (SW); poorly sorted fine to coarse sand, subrounded, composed of sedimentary & igneous clasts, calcareous.	
5940		20		-20- 3	SILTY SAND (SM); very silty brown, fine to coarse sand, subrounded, sedimentary & igneous clasts.	
		30		-30- 4		
5920		40		-40- 5		
		50		-50- 6		
				-55-		
5900		60		-60- 7		
				-65- 8		
		70		-70- 9		
5880		80		-80- 10		
		90		-90- 11		

FIELD DRILLING LOG

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 1-B
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5961.2
Location: Steptoe Valley
Dates drilled: 7·82 to 8·82
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 280 Drill Rig / Mud Rotary 0 - 50 ft., 17.5" tricone bit; 50 - 460 ft., 11" tricone bit.
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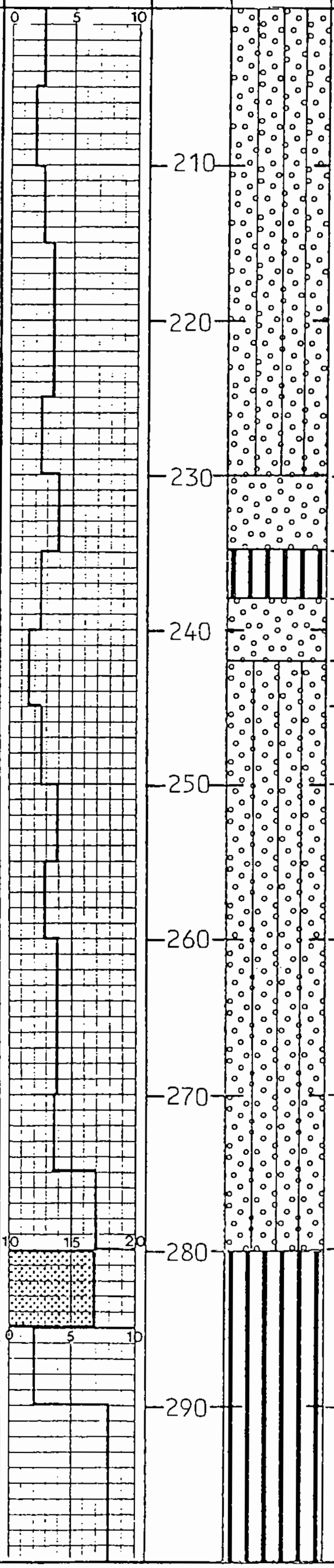
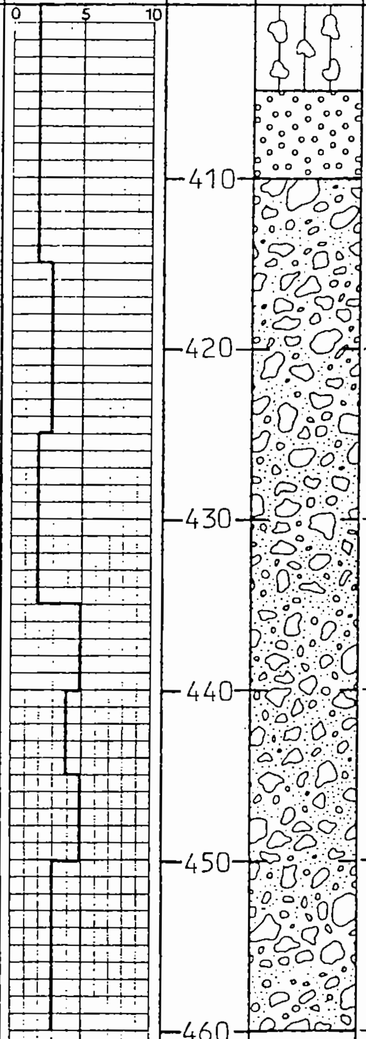


Elev. (feet)	Depth (feet)	Sample No.	Description	Remarks
5760		23	SILTY SAND (SM); brown silty sand, fine to coarse grained, subrounded to subangular, composed of igneous rock clasts.	
	210	210		
		24		
5740	220	220		
		25		
	230	230		
		26	SAND (SW); poorly sorted fine to coarse grained sand.	
		235		
		27	SILT (ML); brown sandy silt	
		238		
5720	240	28	SAND (SW); poorly sorted fine to coarse grained sand.	
		242		
		29	SILTY SAND (SM); light brown silty sand with minor amounts of gravel, very fine to coarse subangular grains.	
		245		
		30		
	250	250		
				Drill rig chattering.
		31		
5700	260	260		
		32		
	270	270		
				Drill rig chattering.
		33		
5680	280	280	SILT (ML); brown sandy silt.	
		34		
	290	290		
		35		

FIELD DRILLING LOG

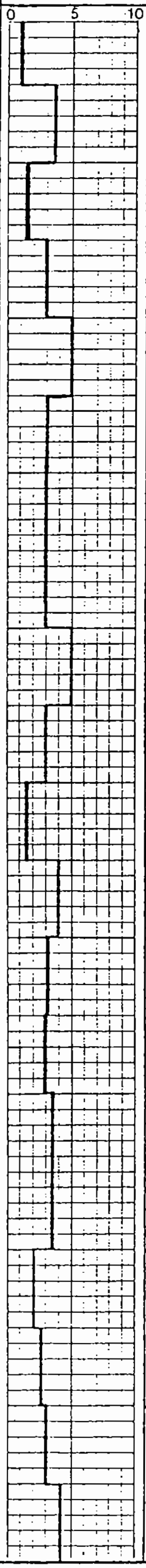
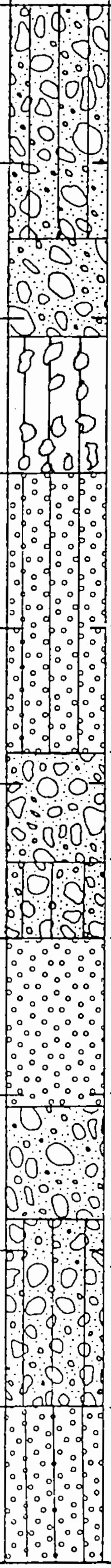
Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 1-B
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5961.2
Location: Steptoe Valley
Dates drilled: 7·82 to 8·82
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 280 Drill Rig / Mud Rotary
0 - 50 ft., 17.5" tricone bit; 50 - 460 ft., 11" tricone bit.
Page 5 of 5



Elev. (feet)	Depth (feet)	Sample No.	Description	Remarks
5560		48	SILTY GRAVEL (GM); silty gravel.	
	405	49	SAND (SW); fine to coarse grained sand, subrounded, rock fragments.	
	410	50	GRAVEL (GW); poorly sorted slightly sandy gravel, subangular to angular, rock fragments.	Drill rig chattering loudly.
5540	420	51		
	430	52		
5520	440	53		Drill rig chattering.
	450	54		
5500	460			T.D. = 460 feet. August 3, 1982.

FIELD DRILLING LOG

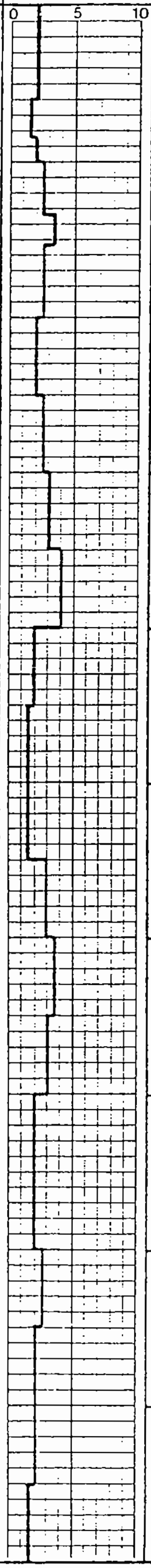
Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 1-C
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5983.0
Location: Steptoe Valley
Dates drilled: August 1982
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 280 Drill Rig/Mud Rotary 0 - 50 ft., 17.5" tricone bit; 50 - 470 ft., 11.5" tricone bit.
Page 2 of 5

Elev. (feet)	Penetration Rate (min/ft)	Depth (feet)	Graphic Log	Sample No.	Description	Remarks
5780-				22	SILTY SANDY GRAVEL (GM); poorly sorted silty sandy gravel, angular to subrounded 1/10" to 5/10" clasts, calcareous.	
				-105-		
				23		
		-110-		-110-		
				24		
				-115-	GRAVEL (GW); poorly sorted sandy gravel, angular, predominantly igneous clasts.	
				25		
		-120-		-120-	SILTY GRAVEL (GM); poorly sorted silty gravel, subangular 1/10" to 5/10" gravel composed of rock fragments.	
5760-				26		
		-130-		-130-	SILTY SAND (SM); brown silty gravelly sand, fine to coarse grained.	
				27		
		-140-		-140-		
5740-				28		
				-148-	GRAVEL (GW); poorly sorted gravel and sand, subangular, 1/10" to 5/10" gravel and fine to coarse sand, composed of rock fragments.	
		-150-		29		
				-155-		
				30	SILTY SANDY GRAVEL (GM); brown silty sandy gravel.	
		-160-		-160-	SAND (SW); poorly sorted silty gravelly sand, fine to coarse grained sand with 1/10" to 5/10" gravel, subangular to angular rock fragments.	
5720-				31		Rig chattering.
		-170-		-170-	GRAVEL (GW); poorly sorted sand and gravel.	
				32		
				-178-	(grading silty)	
		-180-		33	SILTY SANDY GRAVEL (GM); brown silty sandy gravel.	
				-181-		
5700-				34		
		-190-		-190-	SILTY SAND (SM); brown fine to coarse silty gravelly sand, subangular to subrounded, composed of rock fragments.	
				35		

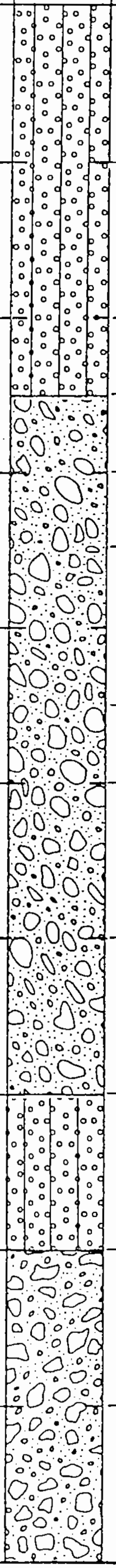
FIELD DRILLING LOG

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 1-C
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5983.0
Location: Steptoe Valley
Dates drilled: August 1982
Datum: Surveyed Elev.
Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 280 Drill Rig/Mud Rotary
0 - 50 ft., 17.5" tricone bit; 50 - 470 ft., 11.5" tricone bit.
Page 4 of 5

Penetration Rate (min/ft)



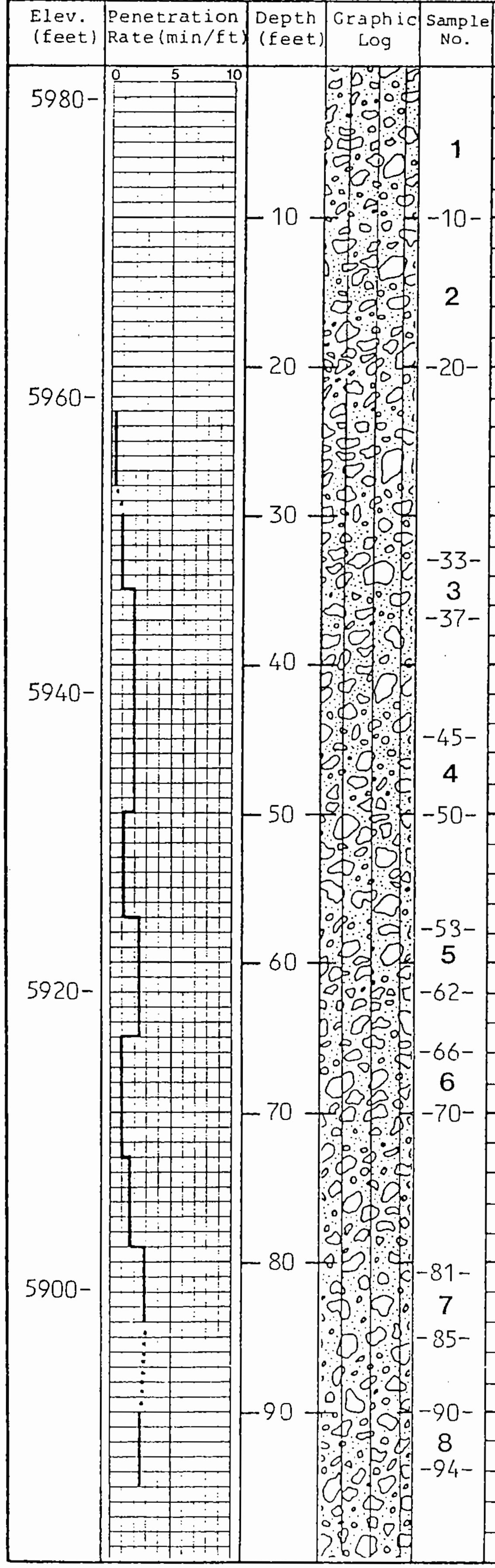
Graphic Log



Elev. (feet)	Depth (feet)	Sam. Loc.	Description	Remarks
5580		46	SILTY GRAVEL (GM); brown poorly sorted silty sandy gravel, subangular to subrounded.	
	310	47		
5560	320	48		
	325	49	GRAVEL (GW); brown sandy gravel, little or no fines, 1/10" to 2/10" gravel, medium to coarse grained sand.	
	330			
	335			
5540	340	50		
	345	51		Drill rig chattering
	350	52		
5520	360	53		Drill rig chattering
	370	54	SILTY GRAVEL (GM); brown poorly sorted silty sandy gravel, subangular to subround, very fine to coarse grained sand.	Drill rig chattering
5500	380	55	GRAVEL (GW); brown slightly silty sandy gravel, subangular to subrounded, very fine to very coarse grained sand clasts composed of igneous rock fragments.	
	390	56		Drill rig chattering

FIELD DRILLING LOG

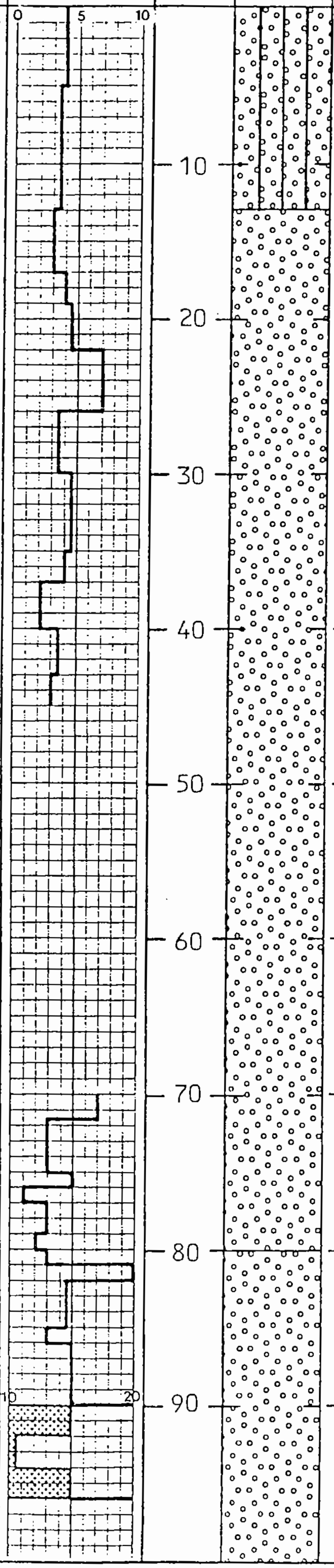
Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: WSW-1
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: ±5982
Location: Steptoe Valley
Dates drilled: July 1982
Datum: Field Approximation
Drilling Method and Bit Sizes: Challenger Model No. 124 Drill Rig/Air and Foam Rotary
0 - 125 ft., 12.25" tricone bit.
Page 1 of 2



Description	Remarks
SILTY SAND AND GRAVEL (GM/SM); poorly sorted silty sand and gravel, subangular gravel, fine to coarse gained sand, composed of rock fragments, calcareous.	

FIELD DRILLING LOG

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 2A
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5840.9
Location: Spring Valley
Dates drilled: 7/82 to 8/82
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 124 Drill Rig/Mud Rotary
0 - 1000 ft., 12.25" tricone bit.
Page 1 of 10



Elev. (feet)	Depth (feet)	Sample No.	Description	Remarks
5840			SILTY SAND (SM); brown silty sand, subrounded to rounded grains composed of quartz and rock fragments, calcareous.	
		1		
	10	-10-		
		2	SAND (SP); brown well-sorted sand, coarse, rounded to subrounded, composed of quartz and rock fragments, calcareous.	
5820	20			
		-23-		
		3		
	30	-30-		
		4		
5800	40	-40-	(grades to fine-grained sand)	
		5		
	50	-50-		
		6	(grades to coarse-grained sand)	
5780	60	-60-		
		7		
	70	-70-		
		8	(grades gravelly)	
5760	80	-80-	SAND (SW); brown sand, poorly sorted, fine to coarse grained, subangular to subrounded, calcareous.	
		9		
	90	-90-		
		10		

FIELD DRILLING LOG

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 2A
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5840.9
Location: Spring Valley
Dates drilled: 7/82 to 8/82
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 124 Drill Rig/Mud Rotary 0 - 1000 ft., 12.25" tricone bit.
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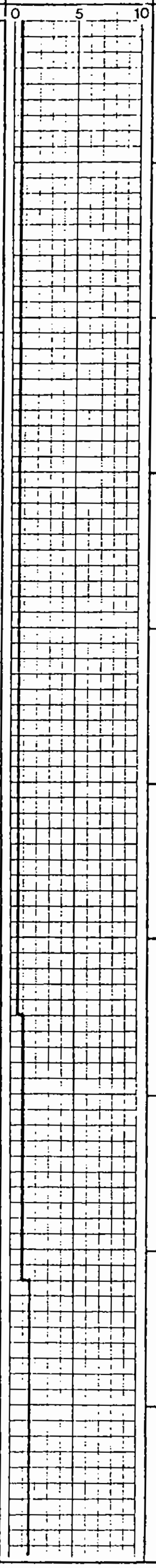
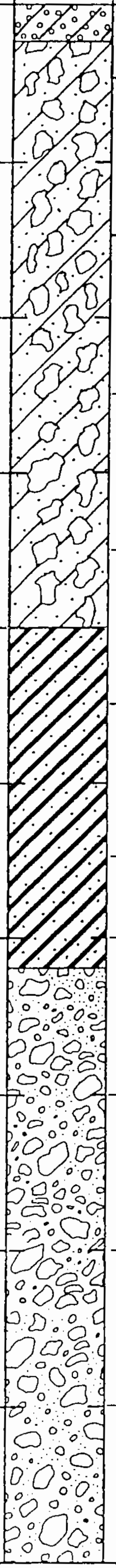
Penetration Rate (min/ft)



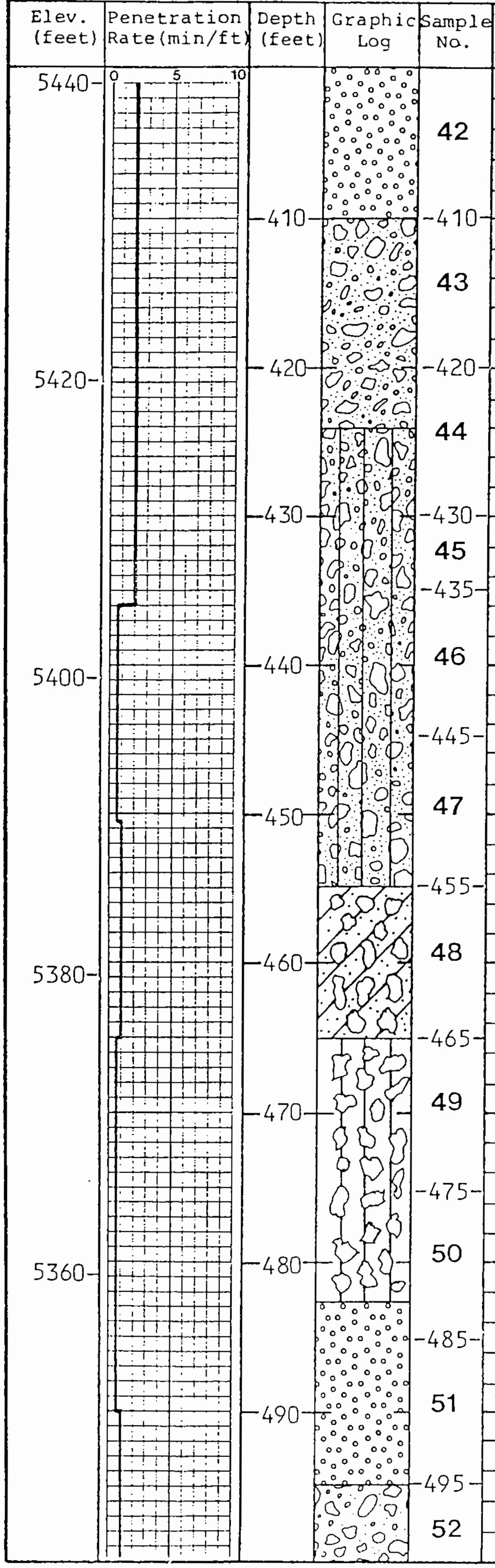
Graphic Log



Elev. (feet)	Depth (feet)	Sample No.	Description	Remarks
5640		21		
	205		CLAYEY GRAVEL (GC); brown, very clayey sandy gravel.	
	210	22		
	215			
5620	220	23		
	225			
	230	24		
	235			
5600	240	25	CLAY (CL); brown sandy clay.	
	245			
	250	26		
	255	27		
5580	260			Drill rig chattering.
		28	SAND AND GRAVEL (GW/SW); brown poorly sorted sand and gravel, subangular to subrounded, fine to coarse sand, small gravel, contains rock fragments, calcareous.	
	270	29		
5560	280	30		
	290	31		

FIELD DRILLING LOG

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 2A
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5840.9
Location: Spring Valley
Dates drilled: 7/82 to 8/82
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 124 Drill Rig/Mud Rotary
0 - 1000 ft., 12.25" tricone bit.
Page 5 of 10



Description | Remarks

SAND (SW); brown poorly sorted fine to coarse sand.

GRAVEL (GW); poorly sorted sand and gravel.

SILTY SAND AND GRAVEL (GM); poorly sorted sand and gravel in silt matrix, slightly calcareous.

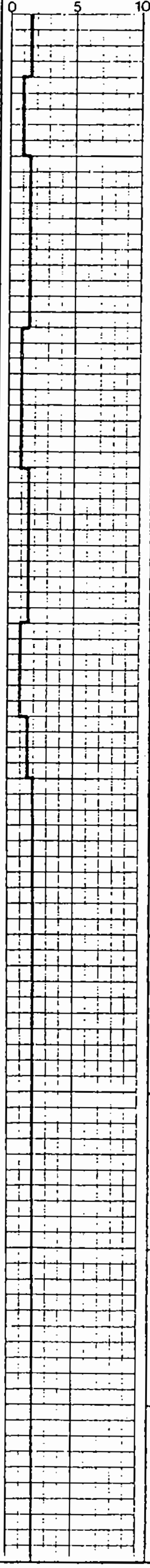
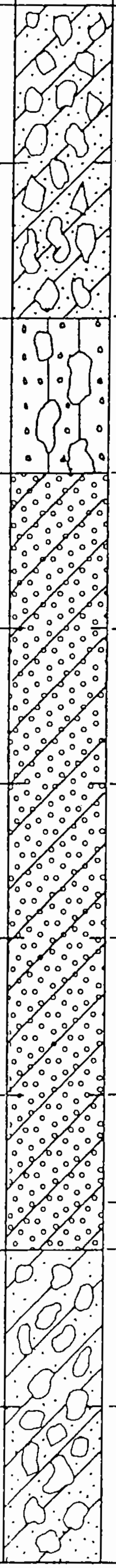
GRAVEL (GC); gravel in yellow-brown sandy clay matrix.

SILTY GRAVEL (GM); very poorly sorted gravel in silt matrix, subangular to subrounded, composed of limestone, sandstone and granite rock fragments.

(grades clayey)

SAND (SW); poorly sorted sand with minor amounts of gravel, medium to coarse grained, subrounded to subangular, calcareous.

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 2A
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5840.9
Location: Spring Valley
Dates drilled: 7/82 to 8/82
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 124 Drill Rig/Mud Rotary
0 - 1000 ft., 12.25" tricone bit.
Page 7 of 10

Elev. (feet)	Penetration Rate (min/ft)	Depth (feet)	Graphic Log	Sample No.	Description	Remarks
5240	 0 5 10			63	CLAYEY SANDY GRAVEL (GC); sand and gravel in clay matrix	
						Drill rig chattering.
		610		610		
				64		
					(grades sandy)	
5220		620		620	SILTY GRAVELLY SAND (SM/GM); gravel in brown silt and sand matrix.	
				65		Drill rig chattering.
		630		630	CLAYEY SAND (SC); brown poorly sorted sand in clay matrix, fine to coarse grained, composed of sandstone, limestone and granitic rock fragments.	
				66		
5200		640		640		
				67		
		650		650		
				68		
5180		660		660		
				69		
		670		670		
				70	(grades gravelly)	
				677		
				71		
5160		680		680	CLAYEY GRAVEL (GC); poorly sorted gravel in yellow sandy clay matrix.	
				72		
		690		690		
				73		

FIELD DRILLING LOG

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 2A
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5840.9
Location: Spring Valley
Dates drilled: 7/82 to 8/82
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 124 Drill Rig/Mud Rotary
0 - 1000 ft., 12.25" tricone bit.
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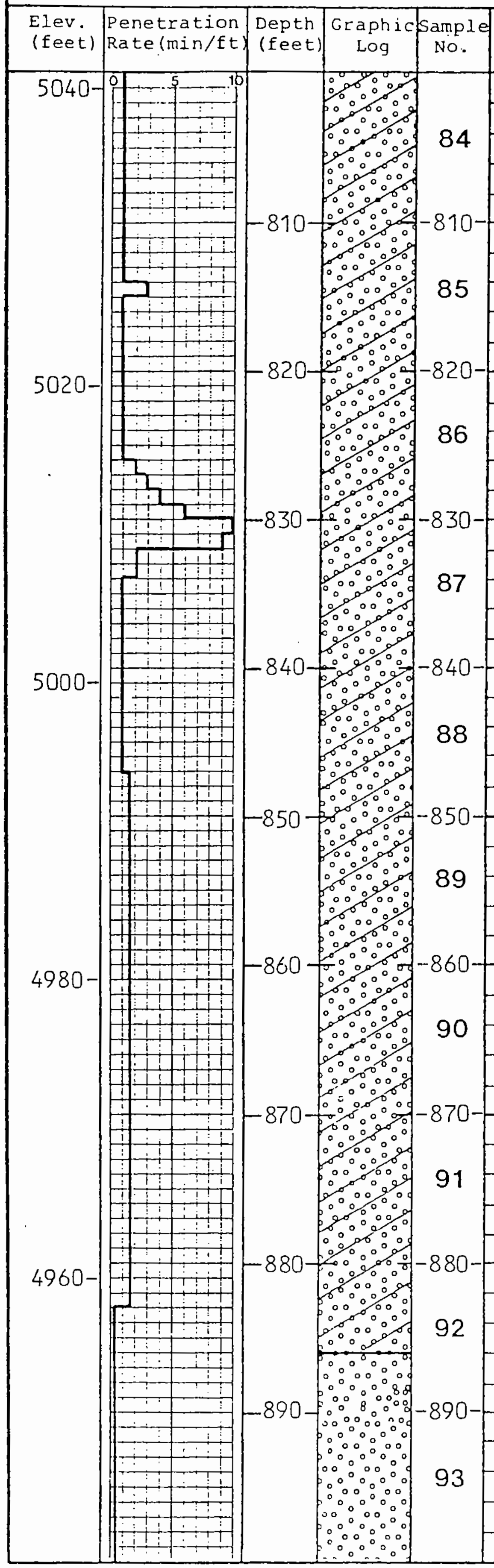
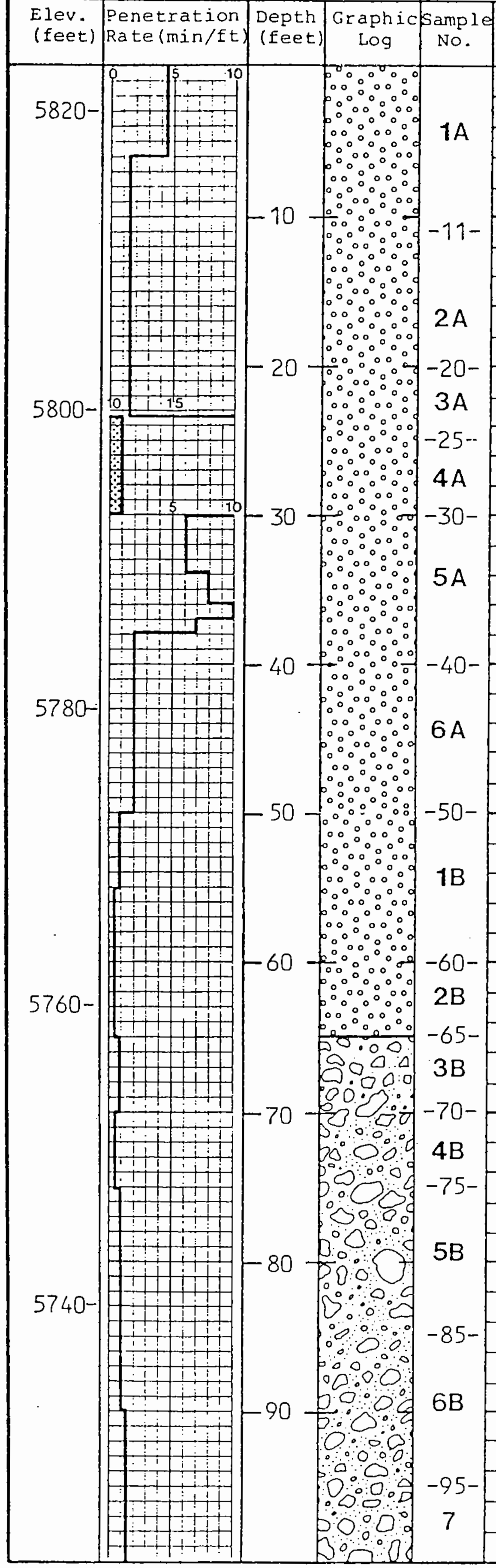


Description	Remarks
CLAYEY SAND (SC); poorly sorted sand in clay matrix.	
	Drill rig chattering.
(grades less clayey)	
SAND (SW); moderately sorted sand, coarse to fine grained, minor amount of silt and clay.	

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 2B
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5822.8
Location: Spring Valley
Dates drilled: August 1982
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 124 Drill Rig/Mud Rotary
0 - 50 ft., 15" tricone bit; 50 - 490 ft., 9 7/8" tricone bit.
Page 1 of 5

Elev. (feet)	Penetration Rate (min/ft)	Depth (feet)	Graphic Log	Sample No.	Description	Remarks



SAND (SP); tan and gray, moderate to well sorted sand, subangular to rounded, composed of sedimentary and igneous rock fragments, calcareous.

SAND AND GRAVEL (GW); brown and gray sand and gravel, 1/10" to 2/10" gravel and coarse grained sand, subangular to subrounded.

Project: WHITE PINE POWER PROJECT Client: LADWP Hole No: 2B

Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada G.S. Elev: 5822.8

Location: Spring Valley Dates drilled: August 1982 Datum: Surveyed Elev. Nov. 11, 1982

Drilling Method and Bit Sizes: Challenger Model No. 124 Drill Rig/Mud Rotary 0 - 50 ft., 15" tricone bit; 50 - 490 ft., 9 7/8" tricone bit.

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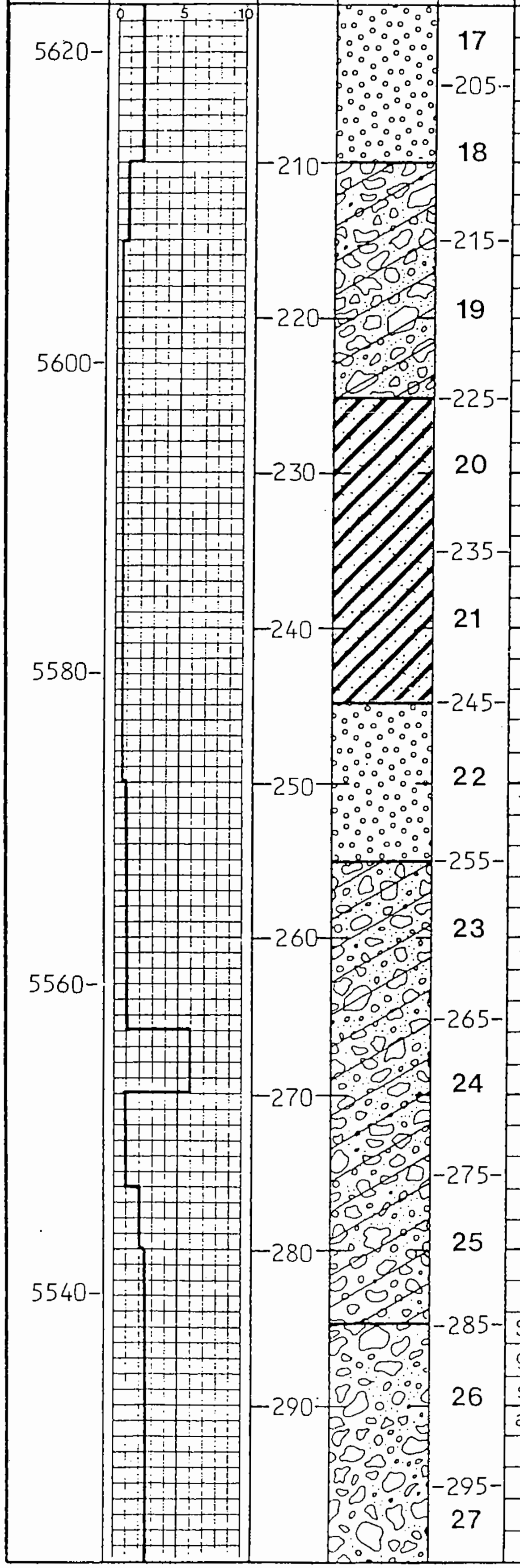
Elev. (feet)	Penetration Rate (min/ft)	Depth (feet)	Graphic Log	Sample No.	Description	Remarks



CLAYEY GRAVEL (GC); brown and gray gravel in brown-yellow clay matrix.

(grades more clayey)

CLAY (CL); brown-yellow sandy clay.

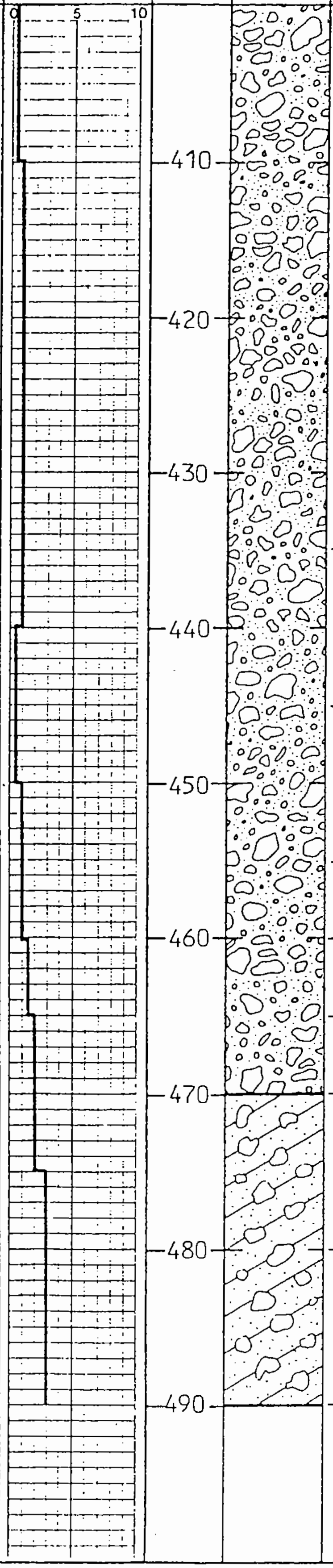
SAND (SP); brown and gray well sorted sand, subrounded, composed of igneous and sedimentary rock fragments.

CLAYEY GRAVEL (GC); sand and gravel in clay matrix, composed of igneous and sedimentary rock fragments.

SAND (SW); poorly sorted sand and gravel, medium to coarse grained sand, gravel up to 2/10", subangular to rounded.

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 2B
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5822.8
Location: Spring Valley
Dates drilled: August 1982
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 124 Drill Rig/Mud Rotary
0 - 50 ft., 15" tricone bit; 50 - 490 ft., 9 7/8" tricone bit.
Page 5 of 5

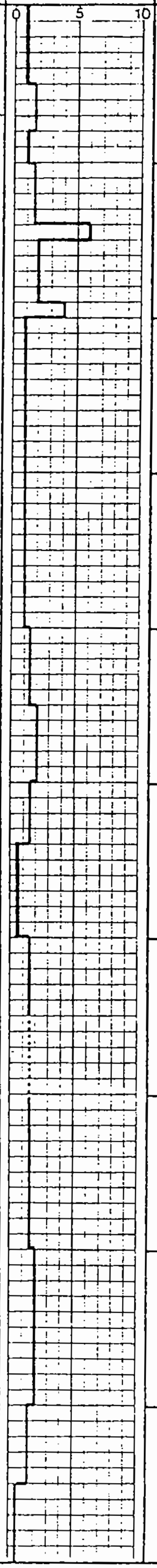
Penetration Rate (min/ft) / Graphic Log



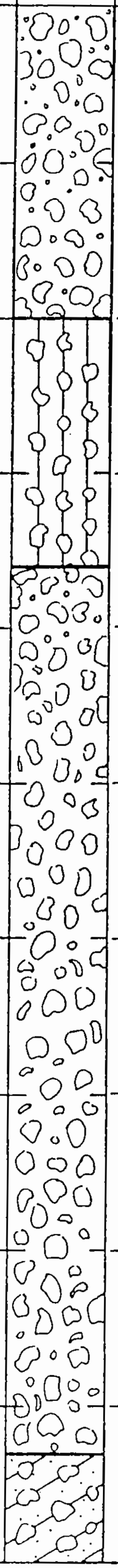
Elev. (feet)	Depth (feet)	Sample No.	Description	Remarks
		37		
5420-			SAND AND GRAVEL (SW/GW); poorly sorted sand and gravel, medium to coarse grained sand, gravel up to 3/10".	
	-405-			
	-410-	38		Drill rig chattering.
	-415-			
	-420-	39		
5400-				
	-425-			
	-430-	40		
				Drill rig chattering.
	-435-			
	-440-	41		
5380-				
	-445-			
	-450-	42		
	-455-			
		43		
				Drill rig chattering.
	-460-			
5360-		44		
	-465-			
	-470-		CLAYEY SAND AND GRAVEL (GC); brown to gray clayey silty sand and gravel, medium to coarse sand, gravel up to 3/10".	
		45		
	-480-			
5340-				
		46		
	-490-			T.D. = 490 feet. August 12, 1982.

Project: WHITE PINE POWER PROJECT
Client: LADWP
Hole No: 2C
Drilling Co.: Thompson Drilling Company, Las Vegas, Nevada
G.S. Elev: 5836.8
Location: Spring Valley
Dates drilled: August 1982
Datum: Surveyed Elev. Nov. 11, 1982
Drilling Method and Bit Sizes: Challenger Model No. 124 Drill Rig/Mud Rotary 0 - 50 ft., 17" tricone bit; 50 - 210 ft., 11" tricone bit.
Page 2 of 3

Penetration Rate (min/ft)



Graphic Log



Elev. (feet)	Depth (feet)	Sample No.	Description	Remarks
		11	GRAVEL (GW/GP); gravel with minor amounts of fine quartz sand and silt, gravel up to 5/10", subangular, composed of sandstone, limestone and granitic rock fragments, secondary calcite cementation.	
5730				
	110			Drill rig chattering.
		12		
	120		SILTY GRAVEL (GM); silty sandy gravel.	
		13		
5710				
	130			
		14		
			GRAVEL (GW/GP); gravel with minor amounts of fine quartz sand and silt, gravel up to 5/10", subangular, composed of sandstone, limestone and granitic rock fragments, secondary calcite cementation.	
	140			
		15		
5690				
	150			
		16		
	160			
		17		
5670				
	170			
		18		
	180			Drill rig chattering.
		19		
5650				
	190			
		20	CLAYEY GRAVEL (GC); clayey silty sand and gravel.	

APPENDIX C

A Report Prepared for

Leeds, Hill, and Jewett, Inc.
1275 Market Street
San Francisco, California 94103

GEOPHYSICAL WELL LOGGING AND SURFACE ELECTRICAL RESISTIVITY STUDIES IN PORTIONS OF SPRING AND STEPTOE VALLEYS WHITE PINE COUNTY, NEVADA

HLA Job No. 12,090,006.01

by

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November 15, 1982

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I INTRODUCTION

This report presents the results of geophysical well logging and surface electrical resistivity (VES) studies conducted in Spring and Steptoe Valleys, covering portions of White Pine County in the vicinity of Ely, Nevada (the work in Steptoe Valley also covered a very small area in Elko County). The results of these studies will be used to help define groundwater regimes for a water supply program for the proposed White Pine Power Project in the area.

The studies were performed in August 1982 by Harding Lawson Associates (HLA) for Leeds, Hill and Jewett, Inc. (LEEDSHILL), as authorized by an HLA Service Agreement dated July 23, 1982, signed by J. S. Nelson of HLA and R. Hungett of LEEDSHILL. HLA field personnel included R. F. Corwin, W. J. Henrich, D. W. Gibbs, E. J. Ticken, and R. J. Palm. G. Nakano of LEEDSHILL selected VES sites and provided field liaison and other assistance.

A. Scope

1. Geophysical Well Logging

Approximately 3000 feet of geophysical well logs were recorded. In both Spring and Steptoe Valleys, the geophysical well logs were recorded in two boreholes, one about 1000 ft deep and the other about 500 ft deep, separated by about 900 ft. The east by the Snake Range and on the west by the Schell Creek Range. VES-5A was located close to logged Boreholes 2A and 2B. Soundings VES-ST1 through VES-ST21 were performed in Steptoe Valley (Plate 1), which is bounded on the east by the Schell Creek Range and on the west by the Egan and Cherry Creek Ranges. Sounding VES-ST7 was located close to logged Boreholes 1A and 1B.

Both Spring and Steptoe Valleys are typical of the Basin and Range province in which the survey area is located, in that they were formed by downward block faulting associated with extensional tectonics and subsequently filled with sediments derived from the surrounding mountain ranges. The sediments are composed of interbedded and intermixed gravels, sands, silts, and clays, and were deposited by alluvial, lacustrine, and eolian processes. Bedrock may be present at a few of the VES sites, but almost all of the sediments are thought to be unconsolidated.

can be be expected in valleys located in this Basin and Range depositional environment.

Quantitative modeling studies of the VES data indicate that it would be difficult to trace most relatively thin layers (less than about 50 feet thick) between VES stations, if these layers lie below a depth of about 200 feet. Therefore, the absence of a relatively thin high-resistivity aquifer layer or low-resistivity clay layer on a given VES section does not necessarily mean that the layer does not exist at that station.

Most of the sediments in both Spring and Steptoe Valleys have resistivities between 20 ohm-m and 250 ohm-m, which indicates good water production potential. Most of the areas having resistivities greater than 250 ohm-m are found at relatively shallow depths in Spring Valley and may represent unsaturated material above the water table. Major areas of low resistivity (below 20 ohm-m) are seen mainly in the deeper, central portions of the two valleys. These areas probably represent clay-rich formations of poor water production potential.

Resistivity values in Steptoe Valley generally are slightly lower than those in Spring Valley. This may be caused by a somewhat higher general clay content, by a different predominant clay type, or by a lower average pore water resistivity in Steptoe Valley.

a) Natural Gamma Log

The gamma probe contains a detector made up of a sodium iodide crystal. The crystal absorbs the gamma ray radiation and converts it to a light flash (scintillation). The light is received by a photomultiplier and is converted to an amplified voltage signal that is proportional to the intensity of radiation. The intensity of radiation is recorded in counts per minute.

The emission of gamma rays is statistical in nature. However, the number of rays counted over a sufficiently long period of time will be practically constant. The period of time needed for an average value is several seconds. This sampling period is known as the time constant. Time constants for this survey were maintained at 5 seconds.

Gamma rays have no electrical charge and no mass and therefore are capable of penetrating rock formations. In general, the depth of investigation for rock formations is 6 to 12 inches; for unconsolidated sediments the depth of investigation is 12 to 18 inches.

b) Normal Resistivity Log

The electrode configuration for the normal resistivity device is shown on the left-hand side of Figure 1. Alternating current (17 hertz) is forced to flow between electrodes A and B. The resulting potential difference is measured between electrodes M and N. The in-line distance between A and M is known as the electrode spacing. The spacing designates the type of normal resistivity log. Spacings of .25 and 2.5 feet were used in this survey. Theoretically, 50 percent of the potential drop occurs along a radial distance from M equal to two times the AM spacing. The radius of investigation, therefore, is approximately equal to 2 AM. Resistivity measurements are made in ohm-feet, but they have been converted to ohm-meters on Plates 2 through 7 for comparison with the VES data.

c) Lateral Resistivity Log

The electrode configuration for the lateral device is shown on the right-hand side of Figure 1. Alternating current is forced to flow between the A and B electrodes. The resulting potential difference is measured between electrodes M and N. For this particular instrument, the lateral designations of .25 and 2.5 feet refer to the distance between the A and M electrodes. According to the manufacturer, the radius of investigation for this lateral configuration is approximately equal to the MN spacing (9.88 ft for the .25 device and 7.5 ft for the 2.5 device).

For reasons explained in the following section, the 2.5 lateral resistivity log readings were assumed to give the best estimate of the true formation resistivity values in the earth. To obtain correct absolute values for this device, a

100° C. The readout on the log gives the temperature (in °C) of the borehole fluid as a function of depth.

B. Electrical Resistivity Measurements

1. Field Procedure

We obtained vertical electrical sounding (VES) data using the Schlumberger array (see Figure 2). This consists of four electrodes arranged in a colinear array. Electrical current (I) is introduced into the earth through the two outer electrodes (AB) while the resulting potential drop (V) is measured between the two inner electrodes (MN). By separating the current electrodes by increasingly greater distances, the electrical current is forced to flow deeper into the subsurface, thus increasing the depth of the sounding. The potential electrodes MN are maintained at a fairly close spacing relative to the current electrodes AB ($AB/MN \geq 4$). MN is increased only when the potential becomes too small to measure accurately. In many cases, lateral resistivity variations or other factors cause a shift in the apparent resistivity data when MN is expanded. Therefore, it was our procedure in the field to overlap the data whenever the shift was made. That is, we would repeat at least two readings using both the initial and the expanded MN. Any measured MN shift then could be compensated for by shifting the data taken at the larger MN spacing to overlap those taken at the smaller MN spacing (see Figure 2).

For the vertical electrical soundings we took readings at 18 different AB/2 values ranging from 1.000 meter to 681.3 meters. Our AB/2 spacings (shown on the data sheets in the Appendix) were chosen to provide distribution at even logarithmic intervals with 6 data points per cycle.

The input current (I) was read on an analog meter included in the transmitter, and the voltage (V) was measured with a digital voltmeter and also monitored on a high impedance chart recorder (see Instrumentation section below). The data were reduced to apparent resistivity values (as described in Section IV; Data Reduction) and plotted in the field to allow any questionable readings to be re-measured.

2. Instrumentation

Almost all of the readings were made using a Scintrex Model IPC-7 resistivity-induced polarization transmitter. This unit has a maximum current capacity of up to about 10 amps and selectable voltages of up to about 1200 volts, and is rated at 1250 watts. Current was input to the earth in the form of a square wave. A complete current cycle consisted of an 8-second positive pulse, an 8-second off period, an 8-second negative pulse, and an 8-second off period. When the Scintrex unit was down for repairs for brief time periods, a backup transmitter sites was good. Vegetation consisted of varying mixtures of sage, shadscale, greasewood, and rabbitbush. Most VES expansions were made along existing dirt roads, with electrodes placed in undisturbed soil adjacent to the road. The weather was clear throughout most of the survey period, with occasional lightning storms. Measurable rainfall, with associated muddy surface soil, occurred only during soundings VES-2 and VES-ST21. In general, variations in soil, terrain, weather, and vegetation conditions were relatively minor and should have had little or no effect on the interpretation of the VES data.

part of this procedure the program computes the theoretical values of ρ_a corresponding to the model. These theoretical values are tabulated in the Appendix along with the observed values and the calculated model thicknesses and resistivities. The validity of each model can be determined by comparing the observed ρ_a with the theoretical values. This is illustrated by the sample curve shown on Figure 2.

clay content is qualitative; a high gamma intensity indicates high clay content (clay-rich soil or shale lithology), and a low gamma intensity indicates low clay content (suggesting a sandy or gravelly soil or a sandstone).

The ultimate sources of potassium in soil sediments are feldspars and mica minerals. Feldspar minerals, as components of igneous and certain sedimentary rocks, weather and decompose into clay minerals. Under conditions of rapid deposition and burial, however, feldspar grains may survive decomposition and mechanically break down into sand and gravel. These feldspar-rich sands and gravels will yield gamma ray intensities comparable to clay-dominated formations.

2. Resistivity Logs

The normal and lateral resistivity logs measure the ability of a formation to conduct electric current through fluid-saturated pore spaces (resistivity is the inverse of conductivity). At a given temperature, the resistivity of a formation is a function of the geometry of interconnected pore spaces, the percentage of fluid saturation, and the ion concentration of the pore fluid. Clay-dominated formations have low resistivities because pore waters are subject to desorption of exchangeable ions from clay minerals. These ions increase the conductivity of the pore water and thereby reduce the resistivity of the formation. Clastic or sand dominated formations less than about 80% of the true formation resistivity. Therefore, throughout this report we will assume that the measured 2.5 lateral resistivity values are essentially equal to the true formation resistivities.

Because the geologic material within a given layer is never perfectly uniform, short-wavelength resistivity variations will be superimposed on the average resistivity value for each layer. In many cases it was relatively easy to estimate a reasonable single average resistivity value for a given layer (for example, the 100 ohm-m value for Layer A in Borehole 2A (Plate 2), discussed below). In some cases, however, it was impossible to pick a single representative resistivity value for a layer. In such cases, only an estimated resistivity range for the layer is given (for example, Layer D in Borehole 1B, shown on Plate 5).

3. Self-Potential Log

The borehole self-potential log is a measure of natural DC voltages that are generated within the borehole. Electrochemical potentials are produced when there is a difference in ionic concentration between the borehole fluid and the formation water. In a clastic permeable formation, a potential forms where the borehole fluid and formation water come in contact. The differences in ion mobilities within the two solutions cause a charge imbalance at the contact, and this imbalance produces a

The temperature log (Plate 2) shows no measurable response to Layer A, indicating that the water in the layer is not geothermally heated and that any cold water flow in this layer is not great enough to transfer a significant amount of heat into or out of the borehole. The caliper log does not show any change in diameter in this interval, indicating either that a very slight amount of natural clay may be acting as a binder to keep the gravel together or that the mud cake wall was functioning properly. The gamma log shows a strong decrease in intensity opposite Layer A, indicating that this layer contains considerably less clay than those above and below it.

The self-potential log shows a negative deflection for Layer A, as would be expected for a gravel saturated with water having a slightly higher salinity than that of the borehole fluid (as discussed later, measured borehole fluid resistivities ranged from about 5 ohm-m to 15 ohm-m, while in-situ formation water resistivities are probably about 10 ohm-m). The response of all four resistivity logs is similar in nature, in that they show a negative "kick" and a slight decrease in resistivity at the upper boundary of Layer A and a strong resistivity decrease at the lower boundary between the gravel and the underlying clay. Examination of the 2.5 lateral resistivity log indicates an absolute resistivity value of about 100 ohm-m in the central part of the layer, away from the influence of the boundaries.

homogeneous layers extending an infinite distance in every direction from the center of the VES. Lateral variations in the resistivity of a given layer, dipping layers, crossing of a fault or contact, or the pinching out of a layer within the range of the current electrodes all will cause distortions of the VES sounding curve. In many cases these distortions can be recognized and removed from the data, but sometimes they cannot be distinguished from distortions caused by additional layers, and so three-dimensional geology with lateral resistivity variations can be erroneously interpreted in terms of simple horizontal layering.

For this particular survey, most of the VES curves showed some evidence of lateral resistivity variations (as tabulated in the Appendix). The distortions were not of the severe type generated when a fault or contact is crossed, but rather were representative of the types of distortions that would be caused by changes in the geoelectric properties of a given layer or by the pinching out of a layer of one resistivity and its replacement by another layer of different resistivity within the range of the current electrodes. The effects of these lateral variations cannot be described quantitatively without using an elaborate 2- or 3-dimensional computer program, but they probably led to relatively minor errors in the derived thicknesses and resistivities of the major layers shown in the interpretation procedure tends to smooth minor "wiggles" in the sounding curves, a VES interpretation usually is a simplified version of the actual complex layered geology beneath the center point of the sounding. Thus, as mentioned above, a single layer on the geoelectric section may represent a number of actual geologic layers having different resistivities. Also, layers that are relatively thin may not be seen on the geoelectric section even if they have a high resistivity contrast with surrounding layers.

This point is important when considering the relationship of resistivity values to formation water content. A geoelectric layer of 80 ohm-m resistivity, for example, may actually consist of a number of thin, relatively high resistivity layers that are good water producers along with one or more thin, low resistivity layers of high clay content or very high resistivity layers of low porosity that are poor water producers. As discussed below, geoelectric sections of moderate to high resistivity probably represent the best formations for water production. However, within such formations there may exist numerous lenses and thin layers of higher or lower resistivity material that have lower water production potential.

where a and m are characteristic of the rock or sediment framework. For unconsolidated sediments in the porosity range of about 10 to 30 percent, a may be taken as 1 and m as 2 (Keller and Frischknecht, 1966).

The average values of ρ_w for water produced from Boreholes 1A in Steptoe Valley and 2A in Spring Valley were about 24 ohm-m and 35 ohm-m, respectively. Both of these are high values representative of fresh water. Taking a representative value of 25 ohm-m for ρ_w, Archie's law gives

$$\rho_f = 25\phi^{-2}.$$

A plot of this equation is shown in Figure 3.

From Figure 3, for ρ_w = 25 ohm-m, formation resistivities in the 20 percent to 40 percent porosity range thought to be typical of most of the study area should vary from about 625 ohm-m for $\phi = 20$ percent to about 160 ohm-m for $\phi = 40$ percent. However, the presence of even a very small amount (a few tenths of a percent or less) of clay in a formation usually limits actual effective in-situ values of ρ_w to no greater than about 10 ohm-m (Keller and Frischknecht, 1966; Grant and West, 1965). (Other factors, such as surface conduction effects in non-clay minerals, also tend to limit in-situ values of ρ_w to about 10 ohm-m.) The curve for ρ_w = 10 ohm-m in Figure 3 indicates that formation resistivities for fresh-water saturated sediments should vary, then, from about 250 ohm-m to about 60 ohm-m in the porosity range between 20 percent and 40 percent.

However, this simple interpretation is complicated by the presence of additional clay in a formation. Because of the ion exchange capacity and surface conduction properties of clays, small additional amounts of clay can cause further large reductions in formation resistivity values. Thus, the amount and type of clay in a given formation must be known in order to unambiguously relate formation resistivity and lithology. Unfortunately, this information can be obtained only from bulk borehole samples; and even when samples are available, the clay percentage is difficult to determine and the type of clay usually can be determined only by an elaborate X-ray analysis.

In order to relate formation resistivity and lithology, then, we must make use of any available "ground truth". In addition to the resistivity values provided in Section VI of this report, other "ground truth" data include published results of resistivity surveys in areas of known lithology and VES data from this survey taken in areas of surface clay deposits. Considering all of these data, we have established the approximate correlations listed in Table 1.

Several points should be noted with respect to Table 1. First, the formation resistivity ranges given are only approximate, and in reality there is considerable overlap between ranges. For this reason, the boundaries between formations of different resistivities shown on Plates 8 through 13 serve only as rough indicators of transitional zones between regions of generally higher or lower resistivity, and boundaries between regions having resistivities near the limits of a given range (e.g., between regions of 19 and 21 ohm-m or 240 and 260 ohm-m) are somewhat arbitrary. Second, no numerical values are given for clay content and porosity, as these would have to be established by actual sampling and measurement for each formation. Third, without knowledge of formation clay content and type it is not possible to choose a single combination of clay content and porosity from the multiple possibilities within each formation resistivity range. Such a choice can be made only by considering the sampling and well testing results from the formation, along with other available geological information.

From the correlations between resistivity logs, geologic logs, VES data, and well production tests shown on Plates 6 and 7, it appears that formations of very low to low resistivity (below about 20 ohm-m) in the logged wells tend to contain significant amounts of clay rather than being of very high porosity. Thus, based on the resistivity log data, formations having moderate to high resistivities (between a lower limit of about 20 ohm-m and an upper limit of about 250 ohm-m) probably represent the best water producers. All formations having

VI SURVEY RESULTS

A. Geophysical Well Logging

1. Spring Valley

a. Geophysical Well Logs

Within the suite of geophysical well logs obtained in Spring Valley (shown on Plates 2 and 3) the combination of natural gamma and resistivity proved to be the most effective in delineating geologic boundaries and identifying sediment composition as indicated by the geologic logs. Detailed descriptions of the correlation between the 2.5 lateral resistivity logs, the geologic logs, and the VES data from Spring Valley are given in the next section.

As expected from the interpretation principles discussed earlier, over most of the logged intervals the combination of relatively low gamma intensity and relatively high resistivity correlated with clean sands and gravels saturated with fresh water, while high gamma intensity together with low resistivity indicated sediments having a high clay content. The self-potential readings also generally responded as predicted by theory, with sandy layers showing negative self-potential deflections. However, the magnitude of the self-potential deflections generally was small, probably because of the low gamma, resistivity, and self-potential response was not sufficiently diagnostic to allow a given layer to be unambiguously designated as clay- or sand-dominated. However, it was possible to assign a reasonable resistivity value, or range of values, to the 2.5 lateral resistivity log readings in these intervals. By combining the lateral resistivity logs, the geologic logs, and the well production test data for Spring Valley (shown on Plate 6), we were able to infer that formations having average resistivities of about 10 ohm-m or less (e.g., Layer B, between about 190 ft and 240 ft in Borehole 2A) had high clay content and were poor water producers, while formations having average resistivities of about 30 ohm-m or greater had low to moderate clay content and were good water producers. Thus, the resistivity boundary between formations that are good or poor water producers in Spring Valley appears to lie somewhere between about 10 ohm-m and about 30 ohm-m. As discussed in Section V, this lower boundary appears to be at about 20 ohm-m. The highest 2.5 lateral resistivity value seen within a good water producing interval in Borehole 2A was about 135 ohm-m. As discussed in Section V, the upper formation resistivity limit for good water production appears to be about 250 ohm-m.

Finally, inspection of Plates 2 and 3 indicates that there are a number of intervals within which the geologic and sandy gravelly clay (Layer B) is clearly indicated by a resistivity drop from 100 ohm-m down to 10 ohm-m. At about 240 ft, the transition from clay (Layer B) to sand (Layer C) is indicated by a resistivity rise from 10 ohm-m to 60 - 80 ohm-m, and the transition from Layer C to a sequence of thinner layers of higher clay content at a depth of 330 ft to 350 ft is indicated by a drop to 35 ohm-m resistivity. The 10- to 20-ft differences between the boundary depth interpretations for the two logs probably are due to the differences in clay content, porosity, and salinity response discussed above.

An example of an interval in which geologic and geophysical well log interpretations differ somewhat is seen in Borehole 2B (Plate 3), between about 45 ft and 210 ft. In this interval, a number of thin layers (10 ft to 30 ft thick) of varying resistivity are shown opposite a continuous sand and gravel section on the geologic log. As most of these layers have resistivities between 60 ohm-m and 175 ohm-m, they fall in the range expected for saturated sands and gravels. Thus, these thin layers probably represent differences in grain-size sorting, porosity, and clay content within the sand and gravel section, rather than gross lithologic changes.

Based on common resistivity log signatures, three discrete continuous geological layers were identified in the two boreholes. These correlative geological layers are represented extending from 420 ft to 1350 ft is a reasonable average of the conductive 10 ohm-m to 40 ohm-m material seen below 420 ft on the resistivity log. No ground truth is available for the 3 ohm-m layer beginning at 1350 ft, which probably represents a saline clay formation.

The 31 ohm-m layer extending from 170 ft to 420 ft on the VES section shows no indication of the 60 - 80 ohm-m Layer C that is seen on the resistivity log and correlates with a sand section on the geologic log. A resolution study of the type described in Section V was conducted on the VES data to determine whether Layer C should have been detectable by the VES sounding. The conclusion of this study was that, for the thickness and resistivity values shown on the resistivity log, Layer C should have been detectable from the VES field data. However, the detectability was marginal, and if Layer C was somewhat thinner than indicated, or if its resistivity contrast was somewhat smaller than that shown on the resistivity log, this layer probably would not have been detectable. Thus, we feel that it is about equally probable that (1) Layer C pinches out or becomes considerably less resistive to the west of Borehole 2A or (2) Layer C was present beneath the VES station but was not detected.

Comparing the averaged resistivity values shown on the VES section with the results of the well production test the expected decrease, was recorded opposite high-resistivity clean sand. This inconsistent gamma response probably was caused by the presence of a considerable amount of potassium-rich volcanic clastics in many of the logged intervals in the two boreholes. The high gamma emission of the potassium in these clastics probably masked most gamma indications of clay content or lithologic boundaries. The relatively constant gamma emission level over such a large percentage of the logged intervals also suggests that most of the sediments in the Steptoe Valley boreholes contain roughly equal amounts of potassium-rich material; thus, they may be poorly sorted in comparison with those in Spring Valley.

The self-potential logs in the Steptoe Valley boreholes showed a response similar to that seen in Spring Valley, with small-magnitude negative self-potential deflections indicating sand-gravel layers. Examples of high-resistivity, negative self-potential intervals defining sand and gravel layers include 350 ft to 400 ft in Borehole 1A and 223 ft to 233 ft in Borehole 1B.

The caliper logs in Boreholes 1A and 1B showed no significant deviations from the bit diameter, indicating some combination of good drilling practice and the possible presence of a clay binder in the logged sediments. The temperature log in Borehole 1B (not shown) was similar in nature to that seen in porosity, and clay content. As none of the layers in either borehole has a resistivity of less than 20 ohm-m, clay content would be expected to be low to moderate throughout; probably less than a few percent. Thus, for example, a change from 1% to 2% formation clay content, which would be difficult to detect on the geologic log, would strongly reduce the formation resistivity. This sensitivity of the resistivity values to small variations in already low clay contents (and to salinity and porosity) probably explains both the generally different formation boundaries and the greater layering complexity on the resistivity logs as compared to the geologic logs.

Based on common resistivity log signatures, two discrete continuous geologic layers could be identified and correlated between Boreholes 1A and 1B. These layers are labeled E and D on Plates 4, 5, and 7. Layers E and D have comparable resistivities in both boreholes, but the thickness of Layer D decreases from 80 ft to 50 ft between the two boreholes. The resistivity log of the layers lying between E and D, labeled as interval F, shows significant variations in resistivities and layer thicknesses between the two boreholes. Correlation of individual layers between boreholes was not possible. Since resistivities in interval F show a general decrease from Borehole 1A to 1B, we can assume that sand content is decreasing and that clay content is increasing in a westerly direction.

pinches out or significantly changes its properties before reaching the VES site.

A computer study of the type described in Section V was conducted to examine this problem. The results of this study indicate that:

(1) If the thickness of Layer D at the VES site is as shown on the resistivity log of Borehole 1B, and the layer is underlain by 34 ohm-m material, it would be marginally detectable by the VES measurement.

(2) If the thickness of Layer D at the VES site is somewhat less than at the borehole, and/or if its resistivity is somewhat lower, it would be difficult to detect in the VES data.

(3) If Layer D at the VES site is of 70-95 ohm-m resistivity and is significantly thicker than the 80-ft value measured in the borehole (i.e., if it extends to greater depth), it would have been detected by the VES measurement.

Thus, we conclude that if Layer D extends to the VES site it probably is thinner and/or less resistive than it is in Borehole 1B (though it still may constitute a good aquifer). If Layer D were thicker and/or more resistive at the VES site than at Borehole 1B, this almost certainly would have been apparent in the VES interpretation.

Based on well production test results from Borehole 1A (Plate 7), the intervals between 110 ft and 120 ft and between 350 ft and 480 ft are good water producers, while the region between these intervals (Layer F) seems to act as a leaky

(6) From the discussion in the previous section, it is apparent that relatively thin deeply buried layers such as Layer C in Spring Valley (Plate 6) or Layer D in Steptoe Valley (Plate 7) would be difficult to track between VES sites.

(7) Formations having resistivities between 20 ohm-m and 250 ohm-m, indicated on the plates by a common lined pattern, probably represent the best potential water producers.

1. Spring Valley

The geoelectric sections for Spring Valley are shown on Plates 8, 9, and 10. Plate 8 shows a north-south section along the east side of the valley; Plate 9 shows a north-south section along the west side of the valley; and Plate 10 shows a series of east-west cross sections.

It is apparent from Plate 8 that most of the formations on the east side of Spring Valley have resistivities that fall between 20 ohm-m and 250 ohm-m, and thus probably represent good potential water producers. Near-surface areas of high resistivity extending from south of VES-7 to VES-17, and from south of VES-19 to VES-20, may represent partially saturated material above the water table. A small area of 290 ohm-m material at the bottom of VES-19 may represent either bedrock or a region of very low porosity sediments.

The resistivity distribution on the west side of Spring Valley (Plate 9) is more complex than that on the east side. The bulk of the material on the west side of the valley has

2. Steptoe Valley

The geoelectric sections for Steptoe Valley are shown on Plates 11, 12, and 13. Plate 11 shows north-south sections in the southern and central portions of the valley; Plate 12 shows north-south sections in the northern portion; and Plate 13 shows an east-west cross section in the central Cherry Creek area.

Resistivity values in this valley appear to be generally lower than those at similar depths in Spring Valley. Although this may be caused by higher clay content and/or higher porosity values in Steptoe Valley, it also may reflect a somewhat different predominant clay type and/or pore water salinity between the two valleys. As noted in Section V, the average resistivity of the water pumped from Borehole 1A in Steptoe Valley was about 24 ohm-m, while the water pumped from Borehole 2A in Spring Valley averaged about 35 ohm-m. Because Archie's law (Section V) indicates that formation resistivities are directly proportional to pore water resistivities, lower pore water resistivity in Steptoe Valley could account for the generally lower measured VES values in Steptoe Valley. However, as discussed in Section V, it should be kept in mind that in-situ pore water resistivities are lower than those measured for pumped samples. In addition, it is not known how representative these measured pore water resistivity values are for their respective valleys.

The VES profile for VES-ST1, ST2, and ST3, shown on Plate 11, indicates that most of the shallow material seen in the three southernmost soundings lies within the 20 to 250 ohm-m range. However, both VES-ST1 and VES-ST3 show relatively clay-rich 14 ohm-m material at depths of a few hundred feet. The two small shallow high-resistivity lenses seen at VES-ST2 may be caused by partial saturation above the water table.

For the profile between VES-ST4 and VES-ST13, all of the shallow and much of the deep material is of greater than 20 ohm-m resistivity, so it may be considered as promising for water production. Two large, deep wedges of low-resistivity clay-rich material come close to the surface at VES-ST5 and VES-ST12. The material in these wedges probably has relatively poor potential for water production.

The east-west cross section in the Cherry Creek area (Plate 13) shows that most of the relatively shallow material in this area is of greater than 20 ohm-m resistivity, indicating good water production potential. Except for VES-ST8, this higher resistivity material is underlain, at depths between about 100 ft and 500 ft, by a thick section of low resistivity clays having poor water production potential.

The north-south section between VES-ST14 and VES-ST19 (Plate 12) is of nearly uniform resistivity, with the great bulk of the material ranging between 20 ohm-m and 60 ohm-m. Although

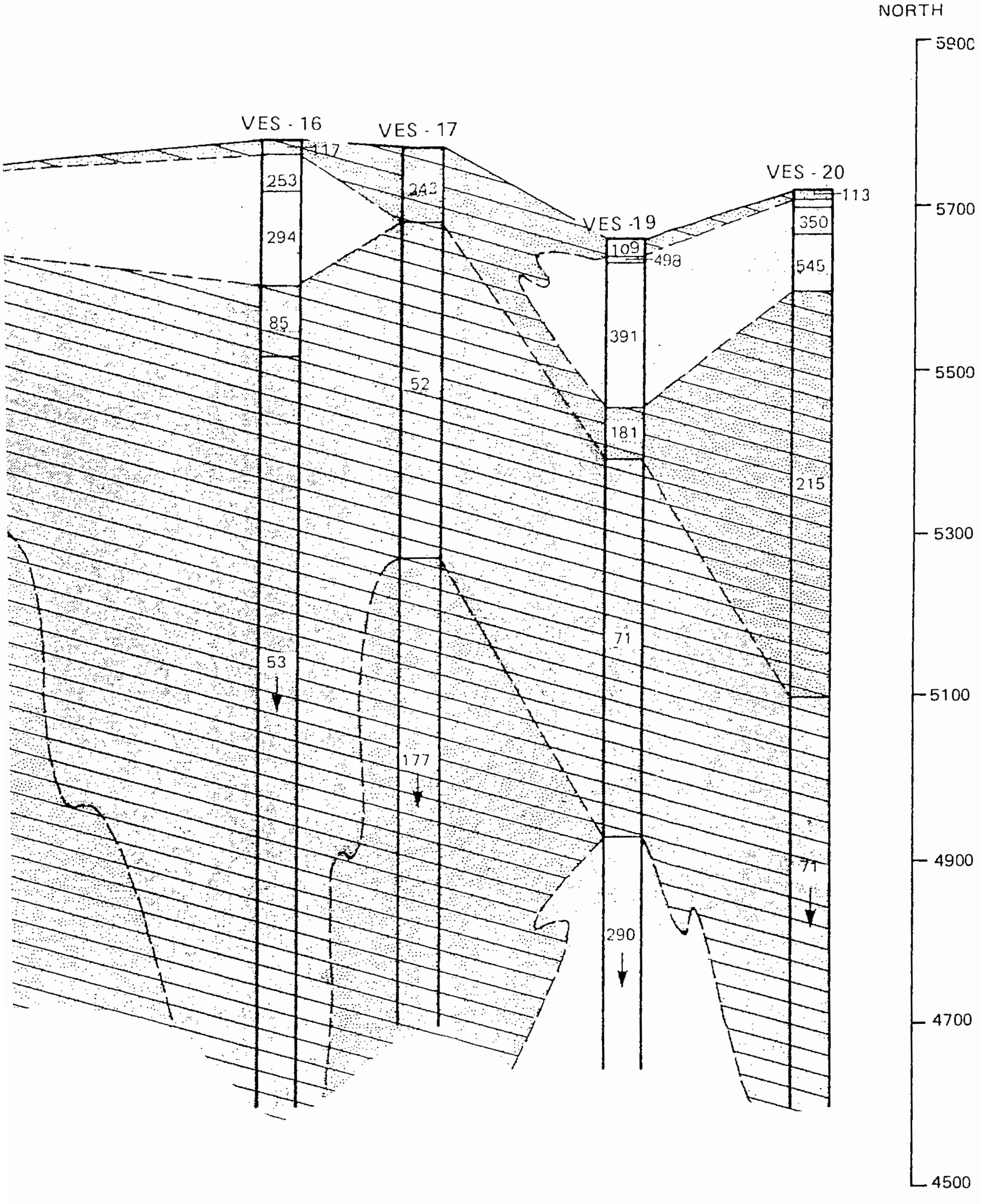
VII CONCLUSIONS AND RECOMMENDATIONS

Based on the geophysical and geological well log data, on production test results, and on theoretical considerations, materials having resistivities between about 20 ohm-m and about 250 ohm-m appear to represent fresh-water-bearing formations containing varying percentages of gravel, sand, and silt, with low to moderate amounts of clay. Such formations should have good potential for water production. Formations having lower resistivities probably are of high clay content and may contain saline pore water. Such formations would have poor water production potential. Formations having resistivities of greater than about 250 ohm-m probably are of very low porosity (and may be consolidated rock in some areas) or may represent zones of partial saturation above the water table. These high resistivity formations also would have poor potential for water production.

It should be kept in mind that the maximum and minimum in-situ resistivities measured by the 2.5 lateral logs were 200 ohm-m and 10 ohm-m, respectively. Thus, our conclusions regarding the nature of materials having resistivities of less than 10 ohm-m or greater than 200 ohm-m are based only on theoretical inference. We are reasonably confident that materials having resistivities of less than 10 ohm-m contain saline pore water soundings in each valley. IP measurements involve the determination of the decay time of an electrical pulse transmitted into the earth. Because decay time is strongly related to clay content (Zohdy et al., 1974), the measurements give an indication of the variation of clay content with depth.

ILLUSTRATIONS

IX ILLUSTRATIONS

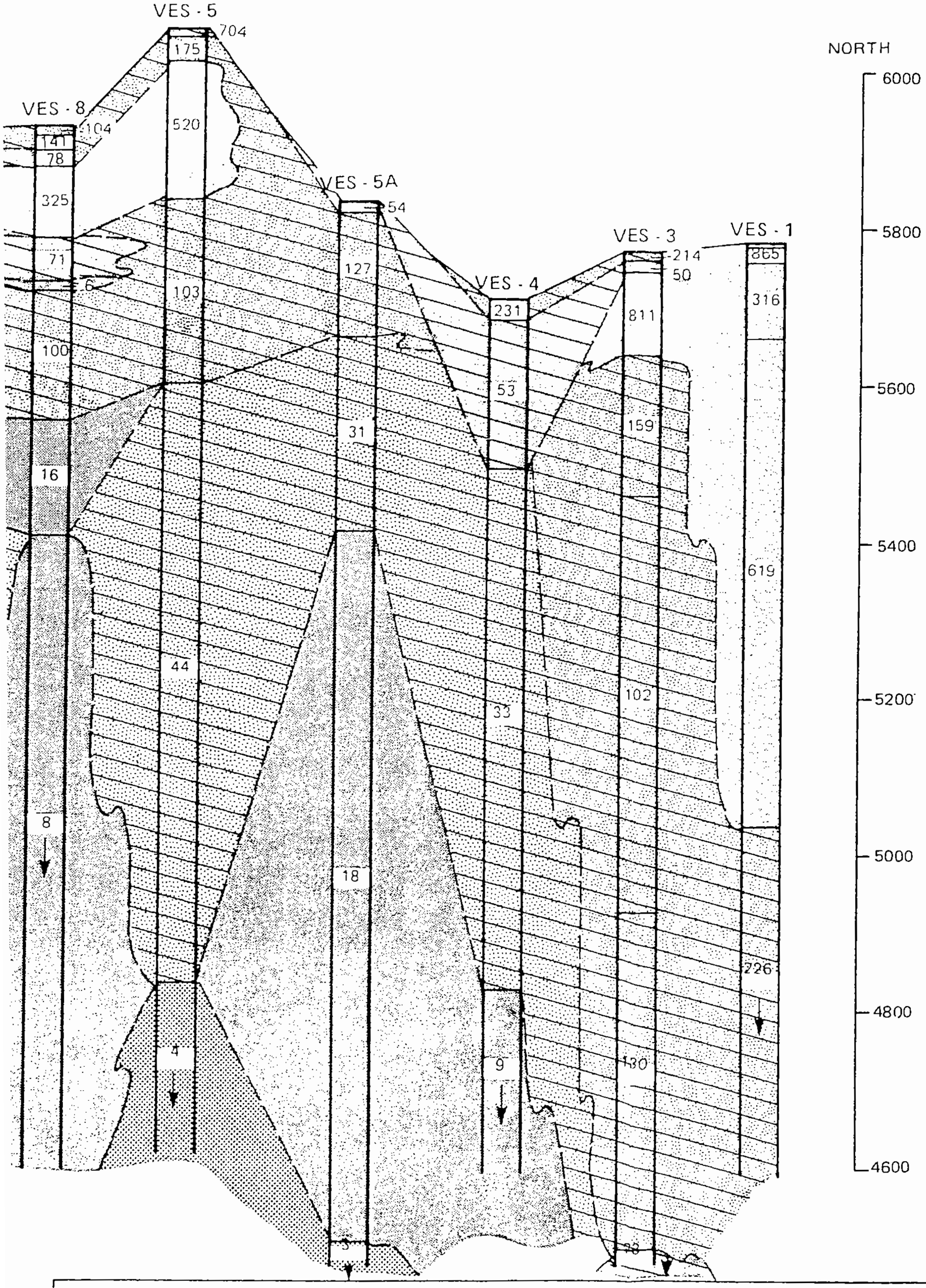


Harding Lawson Associates
Engineers Geologists
& Geophysicists

North - South VES Cross Section
East Side, Spring Valley
White Pine County, Nevada

PLATE
8

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
K. O'Neill	12,090,006.01	R. F. Corwin	9/82		

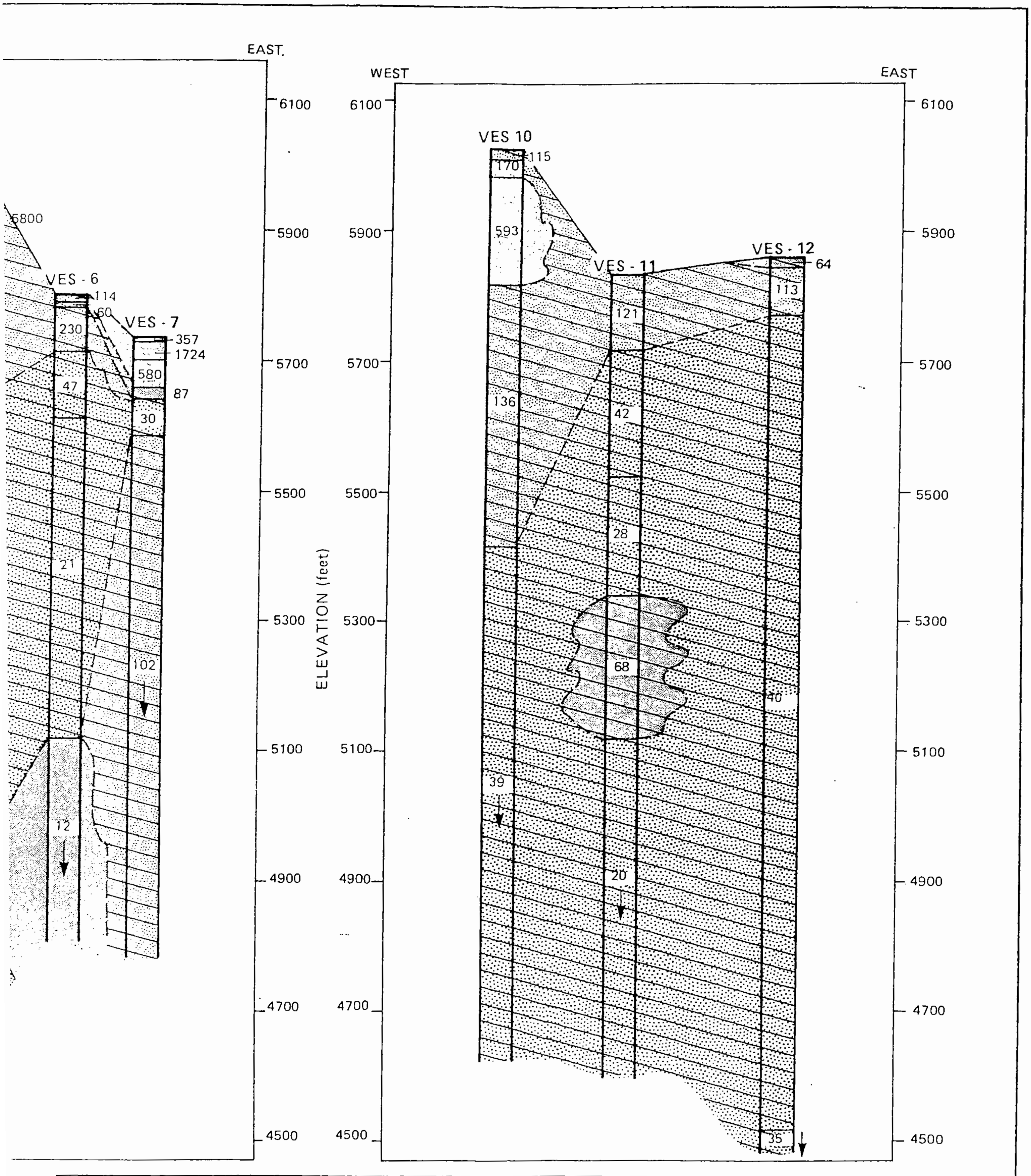


Harding Lawson Associates
Engineers, Geologists
& Geophysicists

North - South VES Cross Section
West Side, Spring Valley
White Pine County, Nevada

PLATE
9

DRAWN K. O'Neill
JOB NUMBER 12,090,006.01
APPROVED R.F. Corwin
DATE 9/82
REVISED
DATE

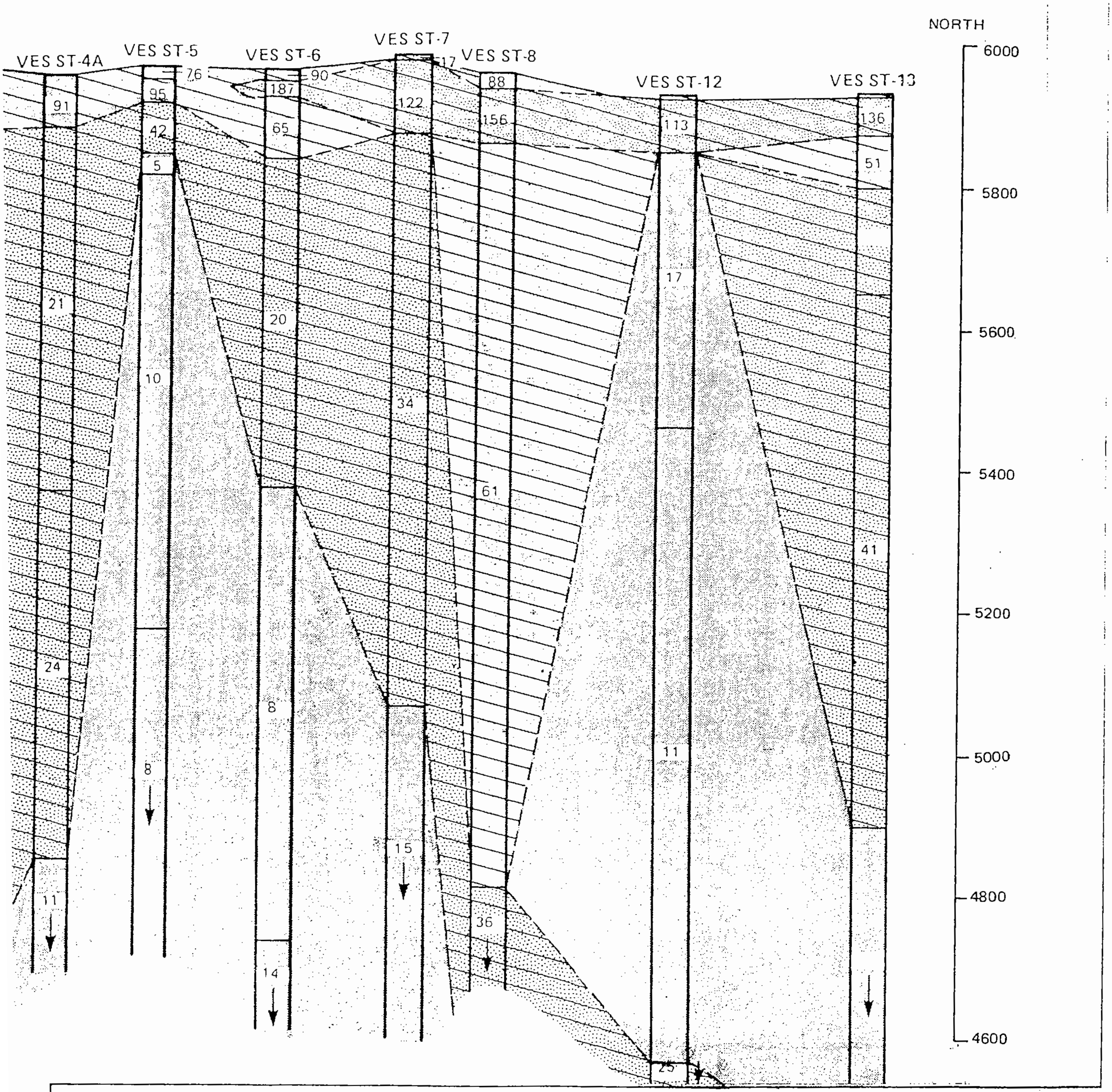


Harding Lawson Associates
Engineers, Geologists
& Geophysicists

East - West VES Cross Sections
Spring Valley
White Pine County, Nevada

PLATE
10

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
K. O'Neill	12,090,006.01	R.F. Corwin	9/82		

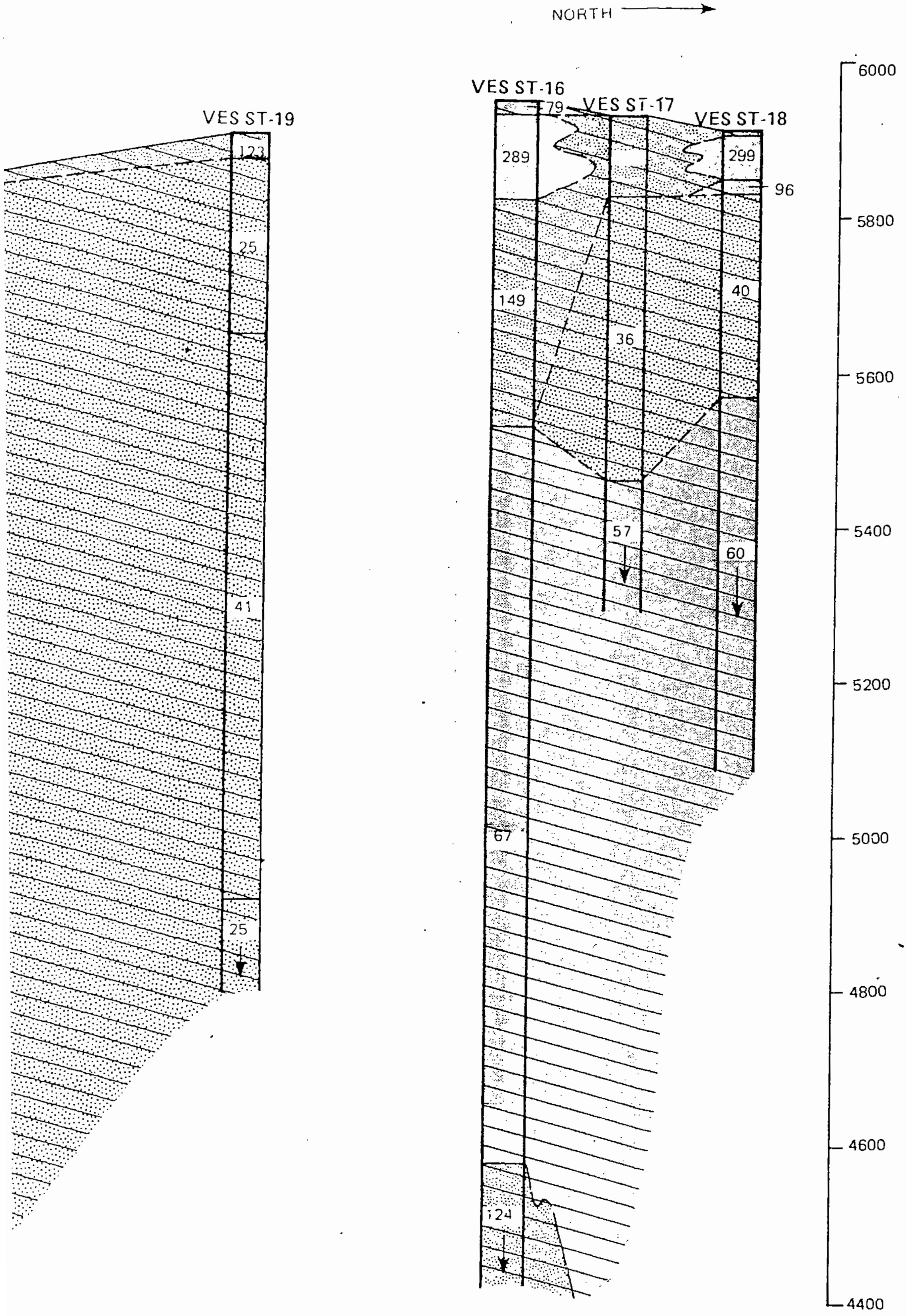


Harding Lawson Associates
Engineers Geologists
& Geophysicists

North - South VES Cross Sections
South & Central Areas, Steptoe Valley
White Pine County, Nevada

PLATE
11

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
K. O'Neill	12,090,006.01	R. F. Corwin	9/82		



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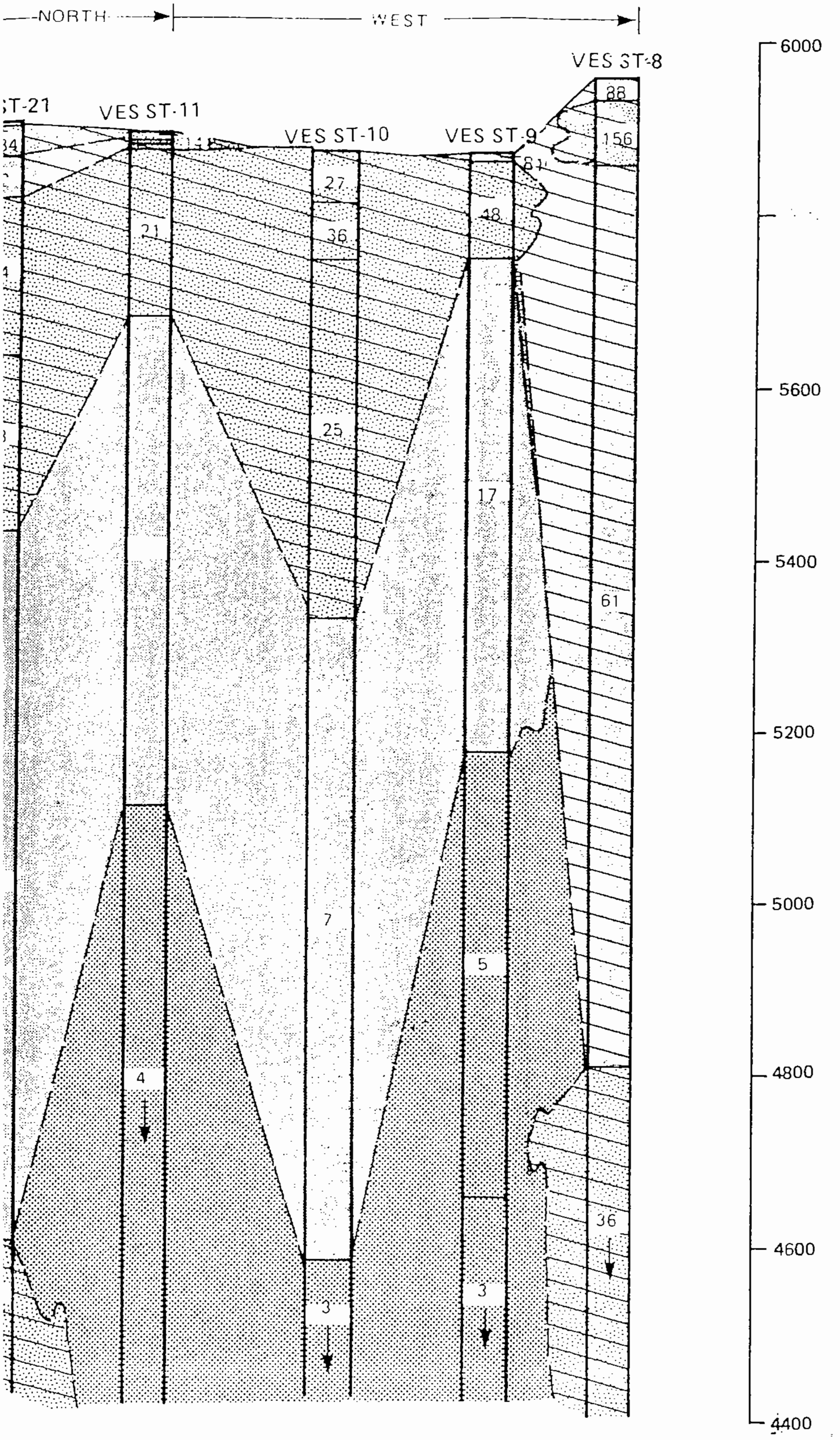
Engineers, Geologists
& Geophysicists

North - South VES Cross Sections
North Area, Steptoe Valley
White Pine and Elko Counties, Nevada

PLATE
12

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
E. O'Neill	12,090,006.01	R. F. Corwin	9/82		



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Engineers, Geologists
& Geophysicists

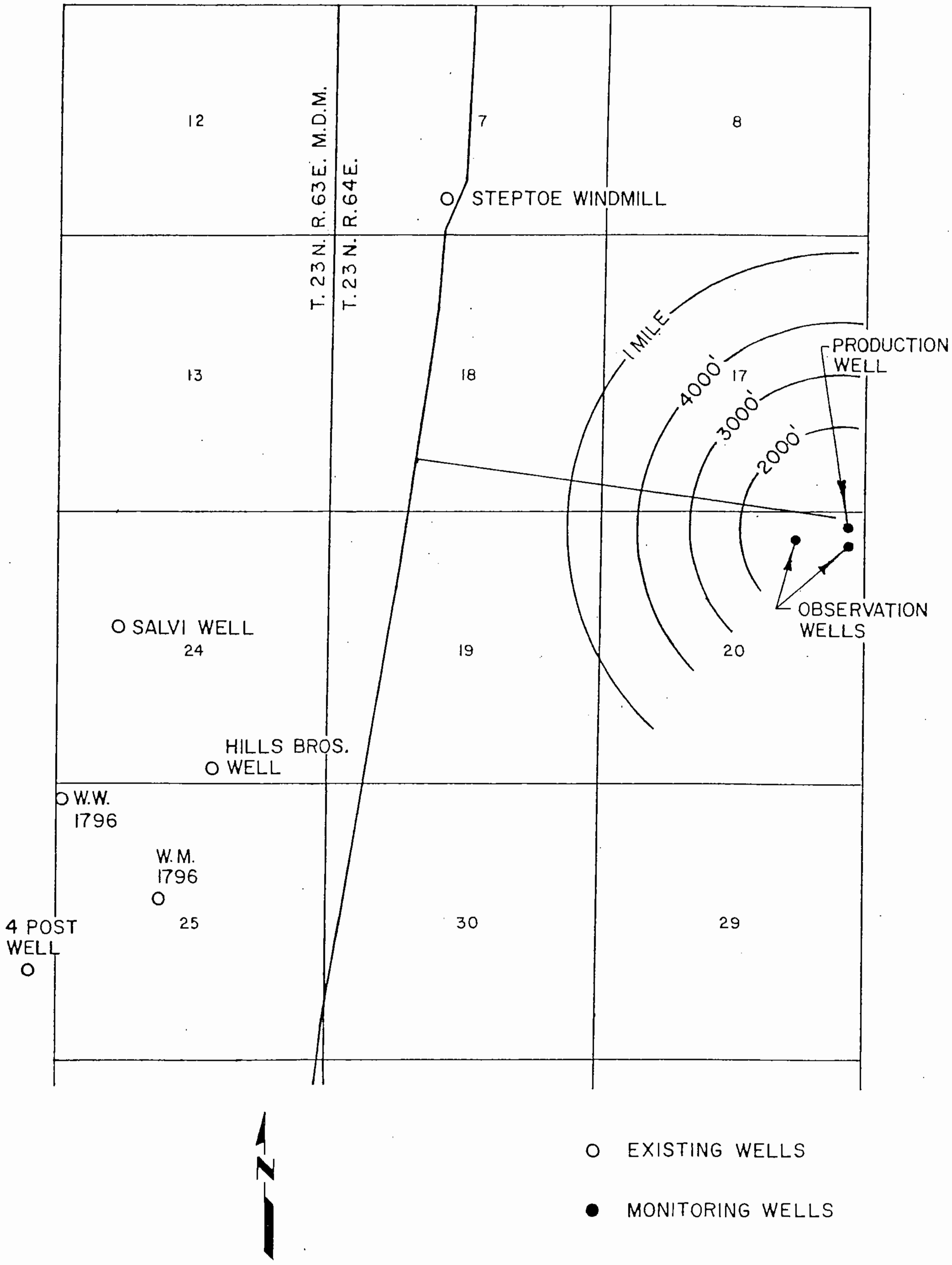
East - West VES Cross Section
Cherry Creek Area, Steptoe Valley
White Pine County, Nevada

PLATE
13

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
K. O'Neill	12,090,006.01	R. F. Corwin	9/82		

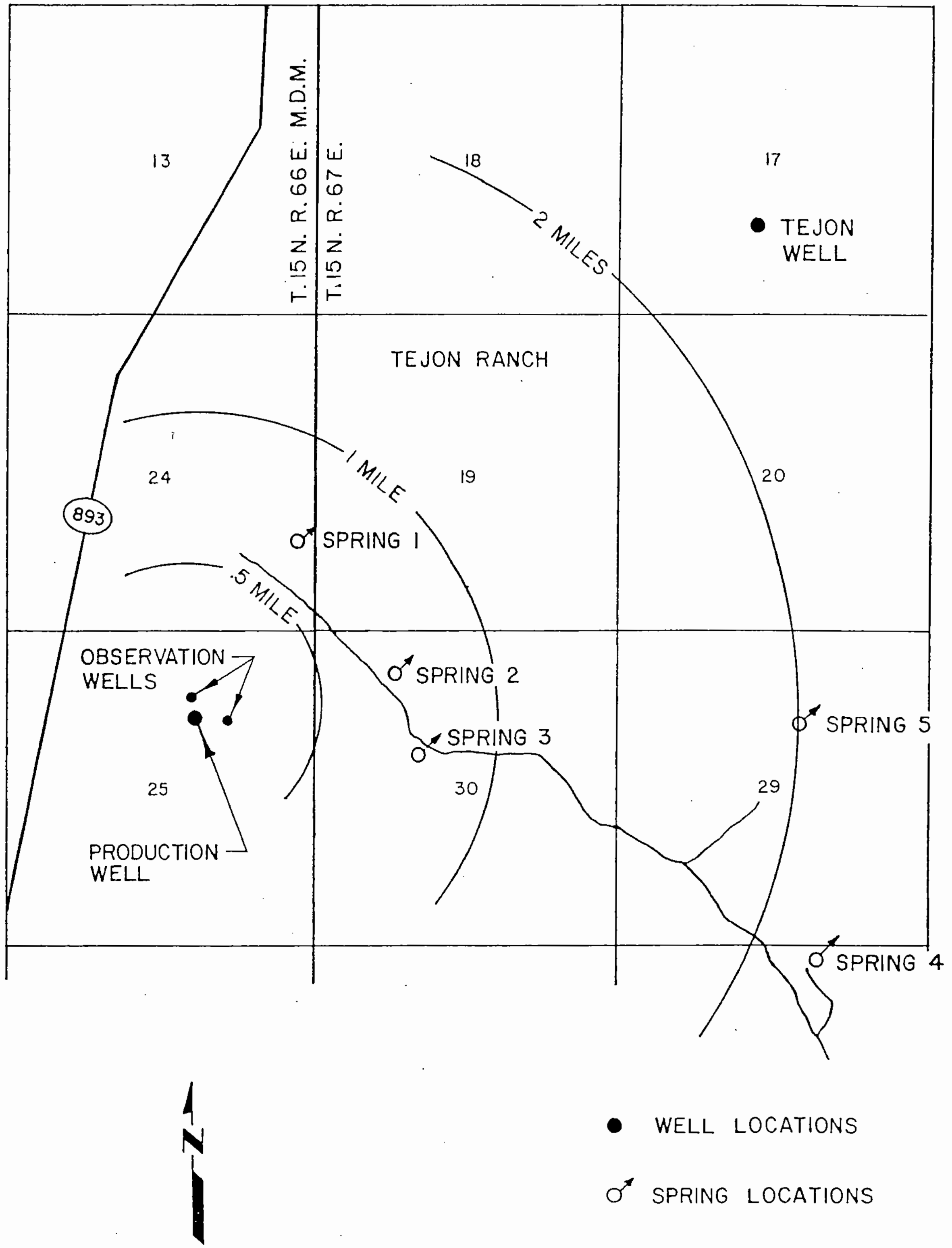
APPENDIX

FIGURES



WHITE PINE POWER PROJECT

WELL LOCATIONS
NO. STEPTOE VALLEY SITE
FIGURE 1



WHITE PINE POWER PROJECT

WELL LOCATIONS
SPRING VALLEY SITE
FIGURE 2

Appendix

ELECTRICAL RESISTIVITY DATA

ELECTRICAL RESISTIVITY DATA

Notes:

(1) ρ_{a_m} = Measured apparent resistivity (ohm-m). Values have been adjusted for MN shifts and slightly smoothed if necessary.

(2) ρ_{a_t} = Theoretical apparent resistivity (ohm-m) generated by computer program INVERT for layered interpretation shown below.

(3) A "yes" listing opposite "distorted?" means that effects of lateral resistivity variations are seen in the VES field curve.

(4) n = layer number for computer VES interpretation.

(5) ρ = resistivity (ohm-m) of layer n.

(6) d = depth to bottom of layer n (ft).

SPRING VALLEY VES DATA

	VES-1		VES-2		VES-3		VES-4		VES-5A		VES-5		VES-6	
AB/2 (m)	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}
1.000	4000	3868	41.2	40.8	540	542	155	203	236	231	337	345	95	93.3
1.468	3650	3656	46.4	46.4	399	385	183	214	132	149	400	390	99	96.3
2.154	3100	3179	53	52.1	290	269	222	222	86	93.3	451	440	112	100
3.162	2400	2417	54.8	55.5	186	198	247	225	67	71.3	481	472	119	104
4.642	1750	1626	54	53.8	126	145	245	224	61	70.9	436	454	105	106
6.813	1200	1083	45.9	47.4	89	103	240	218	80	79.6	360	384	102	107
10.00	820	792	38.3	41.1	84.5	87.2	217	201	96	91.0	299	301	110	113
14.68	540	605	38.5	40.3	106	104	162	166	107	102	232	255	128	126
21.54	430	464	46.8	46.5	160	141	114	121	117	110	252	263	149	142
31.62	390	388	60.2	56.4	212	190	74.5	82.4	120	115	333	302	155	151
46.42	370	380	72.2	65.3	282	244	62.1	61.9	125	113	349	344	139	141
68.13	415	413	67.5	68.1	315	292	52	53.6	105	103	355	367	102	110
100.0	470	461	55	60.9	325	317	46.5	48.2	84	82.1	330	348	69	70.3
146.8	490	502	43	46.0	292	300	42	42.1	59	56.5	255	277	42	40.4
215.4	525	521	32.5	31.3	230	244	37	36.0	35	35.7	175	178	27.5	25.6
316.2	500	500	23	21.9	185	178	31	29.9	23	23.6	98	95.1	19.8	19.6
464.2	440	435	16.5	15.9	123	133	22	23.0	16	16.9	47	46.4	15.5	16.2
681.3	370	350	9.8	10.0	100	111	15.5	16.4	11	11.7	24	22.3	13.1	13.8

n	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ
1	5.2	4005	2.1	34	1.7	823	0.7	140	1.5	396	2.3	297	2.7	90
2	25	869	8.8	77	9.5	215	29	231	2.8	115	9	704	13	114
3	121	316	34	26	11.8	20	219	53	11	55	39	175	19	60
4	229	619	133	132	25	50	887	33	169	127	215	520	88	230
5		226	1232	20	132	811		8.7	416	31	448	103	187	47
6				0.44	313	160			1352	18	1217	44	685	21
7					848	103				3.4		3.8		12
8					1402	131								
9						73								
distorted?	no		yes		yes		no		yes		yes		yes	

SPRING VALLEY VES DATA

AB/2 (m)	VES-7		VES-8		VES-9		VES-10		VES-11		VES-12		VES-13	
	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}
1.000	120	110	111	115	125	126	236	240	90	89.4	240	246	330	328
1.468	130	131	69	75.0	56	54.5	180	190	46	48.9	225	220	320	304
2.154	153	171	50.5	59.5	32	33.7	150	158	32	31.6	168	174	230	242
3.162	210	234	55	63.6	36.5	39.1	134	135	37	34.4	128	125	117	168
4.642	330	322	66	73.6	45	48.6	123	128	47	45.2	100	91.8	90	124
6.813	480	435	79	83.9	55	57.4	121	131	58	57.7	73	81.5	99	123
10.00	640	561	90	94.9	65	66.5	140	143	69	71.0	78	85.0	122	144
14.68	790	681	105	106	78	77.4	158	166	77	84.0	87	91.9	146	168
21.54	800	753	119	118	92	92.1	195	201	90	94.7	98	96.3	170	188
31.62	690	722	131	134	108	111	246	249	100	101	102	95.1	195	203
46.42	390	560	147	151	132	133	302	302	105	100	86	85.6	210	212
68.13	230	332	155	159	155	150	349	344	92	89.6	70	70.0	225	214
100.0	137	161	148	145	161	153	360	356	72	71.9	55	55.2	230	206
146.8	103	94.9	112	110	140	135	310	318	57	54.6	44	46.2	196	181
215.4	95	89.8	69	70.2	100	99.2	240	238	44	43.6	41	42.4	135	141
316.2	101	95.5	41	39.7	63	61.9	150	150	37	38.0	40	41.0	93	103
464.2	104	97.8	22	21.3	38	38.2	82	86.2	33	33.5	40	40.0	81	90.6
681.3	105	99.1	13	12.4	29	29.1	50	54.3	28	28.4	40	38.9	94	104

n	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ
1	3	92	1.6	219	1.3	417	2.1	295	1.6	188	3.8	265	0.9	289
2	5	358	2.2	8.0	1.5	12.7	16	115	2.5	4.0	16	64	3.7	396
3	31	1724	12	91	2.1	4.3	42	170	116	212	90	114	5.0	100
4	74	580	30	141	41	81	206	593	313	42	1343	40	7.0	27
5	94	87	49	78	165	263	611	136	495	28		35	365	227
6	150	30	142	325	368	103		39	719	68			677	25
7		102	196	71		26				20				243
8			218	6.1										
9			375	100										
			525	16										
				8.3										
distorted?	yes		no		no		no		no		yes		yes	

SPRING VALLEY VES DATA

AB/2 (m)	VES-14		VES-15		VES-16		VES-17		VES-18		VES-19		VES-20	
	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}
1.000	258	273	200	200	300	296	430	425	21.9	21.8	460	486	156	125
1.468	195	199	160	166	185	199	200	237	22.4	21.8	220	252	108	120
2.154	110	118	111	125	135	145	75	101	23.4	21.8	82	108	89.0	121
3.162	72	66.1	86	98.0	117	128	49	53.4	21.1	21.8	52	69.1	99.2	128
4.642	63	54.2	73	94.2	117	127	53	60.1	21.0	21.8	58	78.2	127	147
6.813	74	66.0	76	103	121	133	70	81.4	20.4	21.9	77	94.7	175	177
10.00	86	85.0	93	112	132	149	100	105	21.2	22.2	109	115	224	216
14.68	103	106	117	117	165	171	144	129	22.4	22.9	151	145	265	257
21.54	118	128	129	119	200	195	175	153	24.3	23.9	197	183	292	296
31.62	140	151	123	115	225	216	192	169	25.6	25.1	230	224	330	332
46.42	168	174	109	103	235	228	180	169	26.8	25.5	270	261	360	357
68.13	190	197	83	82.1	228	223	145	146	26.0	24.6	290	285	360	356
100.0	210	216	59	61.2	198	192	118	111	23.3	22.1	290	283	340	323
146.8	228	224	47	47.5	145	141	83	83.1	19.0	18.9	230	245	296	273
215.4	220	208	42	41.7	92	93.9	73	75.4	16.3	16.5	157	186	240	221
316.2	146	163	40	39.9	63	66.7	82	84.5	15.2	15.9	132	146	180	172
464.2	88	105	40	39.2	53	57.1	96	102	15.6	16.9	142	142	133	127
681.3	65	67.5	40	38.9	52	54.7	114	120	18.8	19.1	167	165	100	95

n	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ
1	2.3	352	3	229	1.5	541	1.5	721	35	22	1.5	941	0.6	231
2	4.0	96	4	61	18	117	2.2	455	159	29	2.2	435	10	113
3	8.0	19	5	15	63	253	2.8	98	341	14	2.6	74	19	433
4	93	192	103	128	176	294	3.2	15	944	13	4.1	18	53	350
5	445	295		39	269	85	3.5	1.5		29	22	109	122	545
6	656	113				53	94	243			30	498	622	215
7	1031	16					503	52			208	391		71
8		77						177			270	181		
9											735	71		
10												290		
distorted?	yes		no		no		yes		no		yes		no	

STEPTOE VALLEY VES DATA

AB/2 (m)	VES-ST1		VES-ST2		VES-ST3		VES-ST4		VES-ST4A		VES-ST5		VES-ST6	
	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}
1.000	260	259	486	613	1224	1251	154	159	204	212	340	335	177	161
1.468	225	228	570	612	1419	1420	95.6	107	134	142	357	348	141	135
2.154	172	179	635	598	1536	1502	73.4	75.6	78.3	91.0	339	329	112	113
3.162	130	129	620	558	1362	1368	68	67.6	72.8	72.5	257	266	83.7	102
4.642	98	94.6	526	487	887	997	68	69.9	72.7	74.3	166	182	89.9	100
6.813	76	77.2	404	411	441	571	69	72.6	76.5	80.3	113	119	97.0	106
10.00	60	65.0	349	362	241	301	71.4	72.7	82.4	84.0	87	92.0	111	115
14.68	47	51.1	331	333	197	212	68.5	70.0	90.8	85.0	80	84.4	115	120
21.54	39	38.2	294	297	212	196	66	65.2	84.2	82.3	76	77.9	115	114
31.62	33	30.1	251	247	168	174	62	59.0	74.2	73.1	68	65.0	101	96.2
46.42	27	26.5	184	192	131	136	51	51.3	56.6	56.9	50	47.3	78.5	73.2
68.13	23	24.2	137	139	90	95.9	38	42.5	41	39.5	25	29.8	51	51.2
100.0	20	21.4	85	91.3	67	68.7	33.5	35.1	29	27.8	17	17.7	33.5	34.4
146.8	17.5	18.4	59	59.8	53	51.8	29.5	30.6	22.5	22.9	12.3	12.3	25	24.5
215.4	16	16.0	45	46.4	36	38.0	27.5	28.5	20.5	21.5	10.8	10.8	19.2	19.2
316.2	15.3	14.6	43	42.4	27	26.1	29	27.5	20.0	20.9	10.3	10.2	15.6	15.7
464.2	14.4	14.0	39	39.4	20	18.7	26	26.4	19.5	19.5	9.7	9.6	12.8	13.1
681.3	14.0	13.8	35	35.7	16.7	15.9	24.5	24.9	17.7	17.3	8.9	8.9	12.0	12.0

n	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ
1	3.5	282	0.2	376	1.7	947	1.5	275	1.6	334	1.8	296	1.9	198
2	25	77	8.3	630	5.0	2668	2.5	76	3.0	123	4.5	533	15	90
3	194	25	18	244	7.5	1013	5.0	45	4.7	29	6.4	145	37	187
4		13	31	576	9.3	204	25	80	76.1	91	20	76	125	64
5			133	194	9.4	210	99	58.7	586	21	53	95	587	20
6			256	47	76	214	1410	27	1109	24	125	42	1228	8.4
7			293	18	389	57		18		11	156	4.6		14
8			819	47		14					799	10.4		
9				29								7.7		
distorted?	no		no		yes		yes		yes		yes		no	

STEPTOE VALLEY VES DATA

AB/2 (m)	VES-ST7		VES-ST8		VES-ST9		VES-ST10		VES-ST11		VES-ST12		VES-ST13	
	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}
1.000	164	173	231	209	95	85.2	6.0	6.1	73.5	73.2	180	183	400	422
1.468	111	119	175	163	91	83.3	7.2	7.0	76.1	77.7	112	132	410	417
2.154	56	74.7	128	124	85.9	81.5	9.1	8.5	83.1	84.0	87.6	98.6	390	385
3.162	46.2	57.6	94.8	102	82.5	79.4	11.3	10.8	90.9	85.7	81.7	89.5	310	316
4.642	51.8	63.1	80.1	95.3	80.7	75.6	13.8	13.5	74.1	75.6	83.2	94.4	215	235
6.813	65.9	76.3	88.2	96.2	69.1	69.1	16.7	16.5	47.5	54.6	95.5	101	165	175
10.00	82.5	89.0	96.3	102	59.7	61.3	18.6	19.4	23.5	34.0	108.1	105	152	147
14.68	101	99.2	109	112	52.3	54.5	20.8	22.0	20.3	23.1	109.8	106	138	133
21.54	105	106	125	121	48.9	49.9	23.5	24.2	21.2	20.3	107	102	120	117
31.62	112	107	127	126	45.5	46.5	26.2	26.2	21.7	20.3	91.3	90.4	95	95.0
46.42	103	98.7	121	120	39.3	42.0	27.5	27.8	21.5	20.1	66.6	68.4	75	71.1
68.13	80.5	81.2	107	105	34	35.0	28.3	28.4	20.3	19.3	44	43.4	53	52.6
100.0	55	60.3	82	86.0	27	27.0	28	27.7	18	17.8	28	25.9	51	42.3
146.8	44.5	44.6	70	72.1	22.5	20.7	26	25.6	15.5	15.6	20	18.3	37	38.5
215.4	36	36.5	66	64.8	17.6	16.5	22.5	22.0	13.5	13.2	16	15.8	37	37.7
316.2	31.5	32.1	62	60.8	13.0	12.8	17.5	17.0	10.8	10.6	14	14.4	36.5	37.0
464.2	27	27.4	57.5	56.6	8.4	8.9	12.0	11.7	8	8.2	13.5	13.8	34.5	34.3
681.3	22.5	22.2	51	50.9	5.5	5.7	7.8	7.4	6	6.2	14.5	14.6	29.5	29.8

n	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ
1	2	241	2	273	1.3	90	3.7	6	1.3	74	1.6	275	2.4	418
2	3	82	21	88	12	81	58	27	2.7	58	2.9	103	5	541
3	5	17	98	156	125	48	126	36	7.7	141	4.5	42	55	136
4	108	122	1150	61	698	17	540	25	11.1	45	82	113	129	51
5	918	34		36	1217	4.5	1295	7.4	14.7	7	469	17	277	31
6		15				2.9		3.3	210	21	1371	11	1034	41
7									781	11.5		25		19
8										4.1				
distorted?	yes		no		no		no		yes		yes		no	

STEPTOE VALLEY VES DATA

AB/2 (m)	VES-ST14		VES-ST15		VES-ST16		VES-ST17		VES-ST18		VES-ST19		VES-ST20		VES-ST21	
	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}	ρ_{a_m}	ρ_{a_t}
1.000	35.4	33.9	21.1	21.2	122	123	298	302	96.2	97.5	250	248	18.4	24.2	74.5	74.9
1.468	13.5	17.1	23.3	23.6	112	115	313	310	96.0	102	177	192	26.7	30.6	68.9	76.3
2.154	6.5	7.5	28.7	25.7	105	104	293	290	114	111	144	152	38.8	39.5	78.2	80.0
3.162	6.0	5.7	26.3	26.6	92.2	94.8	223	235	138	131	123	133	55.9	49.6	87.5	87.2
4.642	6.6	7.4	21.8	26.4	90.6	91.8	162	174	151	158	119	125	71.5	58.5	95.6	97.0
6.813	8.0	9.9	25.1	26.8	99	99.2	139	141	169	189	118	119	68.9	6.27	107	107
10.00	10.2	12.7	30.4	29.6	115	118	139	136	203	217	112	109	64.7	59.3	111	113
14.68	13.5	16.0	36.3	34.5	153	144	142	140	251	235	91.7	89.9	37.9	48.7	119	113
21.54	17.2	19.3	37.3	38.8	187	174	142	141	248	235	65.6	64.6	29.6	36.4	107	103
31.62	21.1	22.4	36.8	39.3	207	201	132	135	203	206	43.2	42.8	27.9	28.1	79.1	83.4
46.42	25.4	25.0	34.6	35.2	213	219	117	118	139	151	31.5	31.4	29.5	24.7	60.7	60.2
68.13	28	27.1	28.5	28.9	209	220	86	90.5	91	93.8	26.5	28.1	28	23.5	34.5	41.3
100.0	29	29.0	25	23.8	210	203	60	63.6	63	59.2	26	28.5	25	22.6	31	31.0
146.8	30.5	31.4	22	21.3	180	173	47	47.8	49	48.8	27.5	30.2	22.5	21.6	24	26.9
215.4	33.5	34.8	20	20.7	127	138	43	43.8	49	49.8	32.5	32.5	20	20.9	20.5	23.6
316.2	39	39.1	21	21.1	102	109	45	45.8	51	52.9	34.5	34.2	19.5	20.4	17	19.0
464.2	42.5	43.3	22.5	22.6	92	91.5	50	49.1	54	55.6	35	34.2	20	20.0	14.5	15.4
681.3	45	46.3	25	25.0	90	88.3	53.5	52.0	56	57.6	33	32.5	20.5	19.4	15.2	15.3

n	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ	d	ρ
1	1.4	70	2.0	18	3.1	129	1.9	273	5.5	95	1.7	356	2.3	18	5.8	74
2	2.1	29	5.5	37	18	77	4.7	478	60	299	32	123	3.8	83	40	139
3	2.5	5.3	18.7	19	127	289	7.0	39	79	96	257	25	9.3	147	86	62
4	6.4	1.6	45.4	93	420	149	104	152	343	40	994	41	23	46	270	24
5	344	29	991	20	1385	67	473	36		60		25	88	21	472	38
6	55		36		124		57						101	57	1301	7.5
7		45											1391	20		48
8														17		
distorted?	yes		yes		yes		no		yes		no		yes		yes	

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APPENDIX D

head on the boundaries of the aquifer system are given as either Dirichlet or constant head conditions,

$$h\left(M_2,t\right) = h^* \qquad (D.3a)$$

where h* is the known head, or Neumann conditions which control the flux through a boundary, M_2, or

$$\underline{q} \cdot n = q^* \qquad (D.3b)$$

q* is the known flux and $\underline{n}$ is a unit vector normal to the boundary.

At the beginning of the simulation period, the initial conditions or initial state of the basin are given as

$$h\ (\underline{x},\ o) = g(x) \qquad (D.4)$$

where g is a function defining the spatial variability in the hydraulic head at time = 0.

D..2 Numerical Solution

The Galerkin finite element method is used to obtain the numerical solution of the mathematical model, described by equtions (D-1, D-4). In contrast to finite difference methods, where A is the domain of the problem. (32) These integral equations may be simplified to a system of ordinary differential equation in time, or

$$C\dot{\underline{h}} + H\underline{h} + \underline{f} = 0 \tag{D.8}$$

where $\underline{h}$ is h x 1 a column vector of the nodal values of the hydraulic head, $\dot{\underline{h}}$ is the time derivative of $\underline{h}$. Typical elements of C and H (n x n coefficient matrices) are:

$$Cij = \int_A SNi\ Nj\ dA \tag{D.9a}$$

$$Hij = \int_A \left[Tx\ \frac{\partial Ni}{\partial x}\ \frac{\partial Nj}{\partial x} + Ty\ \frac{\partial Ni}{\partial y}\ \frac{\partial Ni}{\partial y} \right] dA \tag{D.9b}$$

The $\underline{f}$ vector contains the source, sink term and the boundary conditions of the problem.

A finite difference approximation is used to solve ordinary differential equations described by equations (D.8). Discretizing the simulation period into a series of discrete intervals, then an implicit finite difference solution of equation is

$$C \left\{ \frac{\underline{h}^k - \underline{h}^{k-1}}{\Delta t} \right\} + H\underline{h}^k + \underline{f} = \underline{0} \tag{D.10a}$$

where k is an index of the time step. The head values at any time Δt, is then,

APPENDIX E

GROUNDWATER DRILLING
MONITORING PROGRAM
APPENDIX E

Technical Report

For The

WHITE PINE POWER PROJECT

Prepared By

CIVIL DESIGN STAFF
CIVIL, STRUCTURAL ENGINEERING AND SERVICES SECTION
POWER DESIGN AND CONSTRUCTION DIVISION
LOS ANGELES DEPARTMENT OF WATER AND POWER

January 1983

GROUNDWATER DRILLING
MONITORING PROGRAM
APPENDIX E

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LIST OF FIGURES

1.0 INTRODUCTION

This report summarizes the results of a program conducted by Civil Design personnel of the Power Design and Construction Division to monitor water levels and flow rates in selected wells, springs, and seeps during the White Pine Power Project (WPPP) aquifer pumping tests in Steptoe and Spring Valleys. Data were recorded and plotted on a chronological basis to establish a pretest data base and to observe any water level fluctuations. The plotted data indicates the pumping of the aquifer wells had no influence on the monitored locations. Any observed trends in the data are probably seasonal in nature and unrelated to pumping activity. A more detailed discussion of the data follows in the analysis section of the report.

3.0 MONITORING SITES

3.1 Steptoe Valley

Four stockwatering wells were initially selected for the monitoring program in Steptoe Valley. Two wells were later added, making a total of six stockwatering wells monitored within a three mile radius of the test production well. The approximate well locations are shown in Figure 7. A brief description of each of the wells follows:

The 4 Post Well, a later addition to the monitoring program, Well WW1796 and the Salvi Well are all abandoned 4-inch-diameter stockwatering wells with casings projecting above ground. The Hills Brothers Well, later added to the program, and Well WM1796 are both pumped seasonally for stockwatering purposes. Although efforts were made to monitor these wells after any pumping influence, some measurements were taken when the well was being pumped (the data points are so noted on the chronological plots). The well referred to in this report as the Steptoe Valley Windmill is used for stockwatering purposes. The windmill was pumping continuously but was shut off one day before aquifer pumping started.

Chronological plots of water levels for these wells are shown in Figures 3 through 8.

3.2 Spring Valley

Five springs and seeps and one abandoned stockwatering well located within a 2-1/2-mile-radius of the test production well site were selected for the monitoring program. The locations of the wells and springs are shown in Figure 8.

At Springs 1, 2 and 3, observation wells with a

4.0 ANALYSIS OF OBSERVATIONS

4.1 Steptoe Valley

The Four-Post Well, Wells WM1796, WW1796, and the Salvi Well all showed a slight downward trend from the beginning of the monitoring period until approximately the end of August. The water levels then remained relatively constant until the latter portion of September. The water levels in late October showed a marked upward swing. The pumping test period, beginning on August 29 and ending September 29, clearly did not influence any water levels during the monitoring period. The downward trend at the beginning of the monitoring period may indicate a possible seasonal fluctuation. The upward swing at the end of the monitoring period is probably due to wet weather conditions in the previous week.

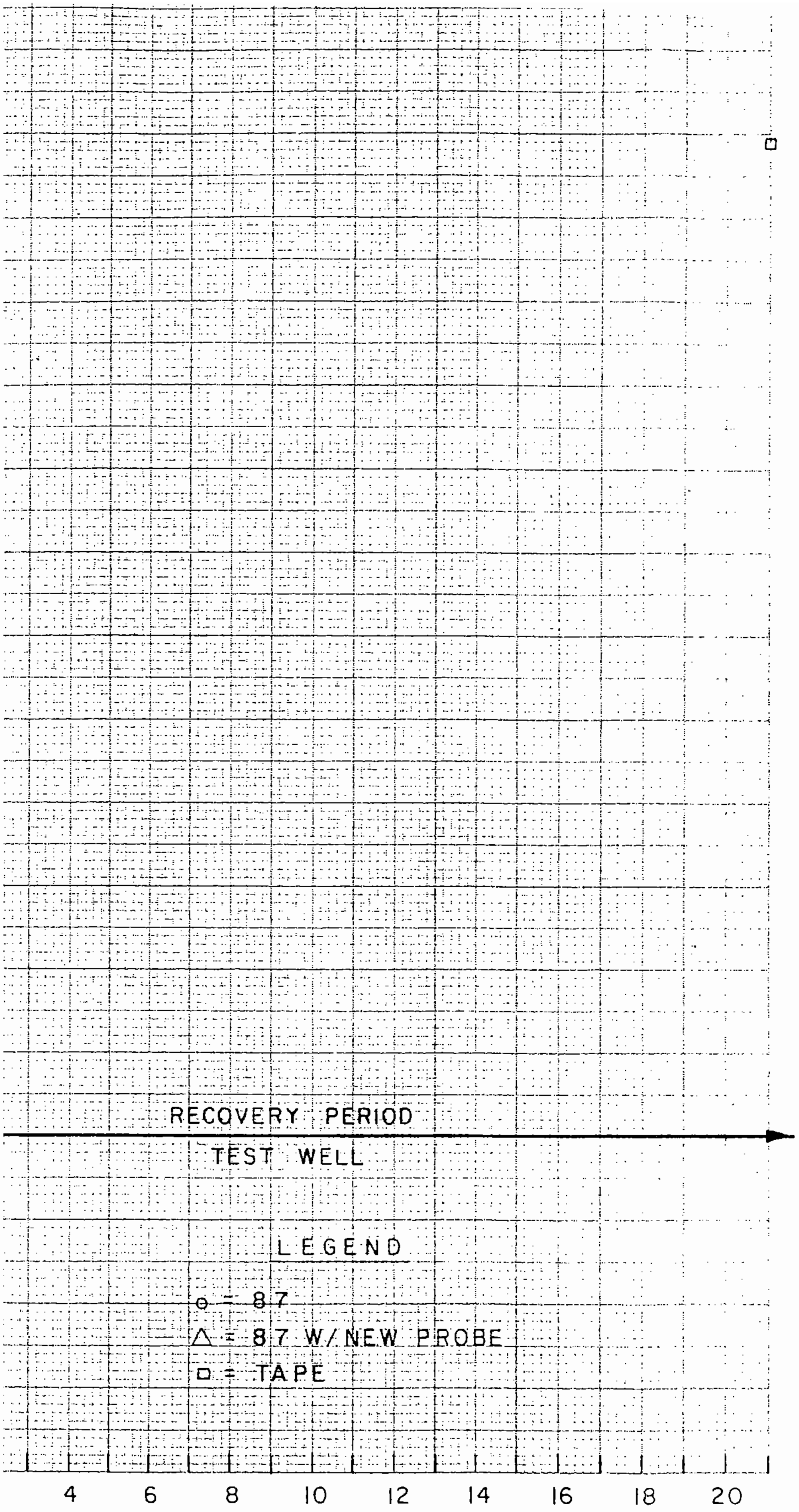
The Hills Brothers Well did not exhibit fluctuations during the monitoring period. However, since daily monitoring of the well began in the latter portion of August, a downward trend during August as observed in the other wells was not apparent. This well did exhibit an upward swing after the wet weather conditions as did the other monitoring wells.

The Steptoe Valley Windmill exhibited large fluctuations at the beginning of the monitoring period in August. These fluctuations were probably due to the sporadic pumping of the windmill. During the period of aquifer pumping, a gradual upward trend was noted. This rise in water levels was also observed in the other monitored wells and is probably due to wet weather conditions.

be a reliable indicator of piezometric levels and not subject external mechanisms which might cause fluctuations.

Flow and depth to water below top of casing measurements for Springs 4 and 5 did not show any trends throughout the duration of the monitoring program. Variations in the flow values are mainly due to different monitoring procedures.

During and after the period of the pumping test (September 16 through October 3), the water level measurement of the springs and wells showed no deviation from their previous trends. No fluctuations were observed which could be correlated with the timing and duration of the test pumping.



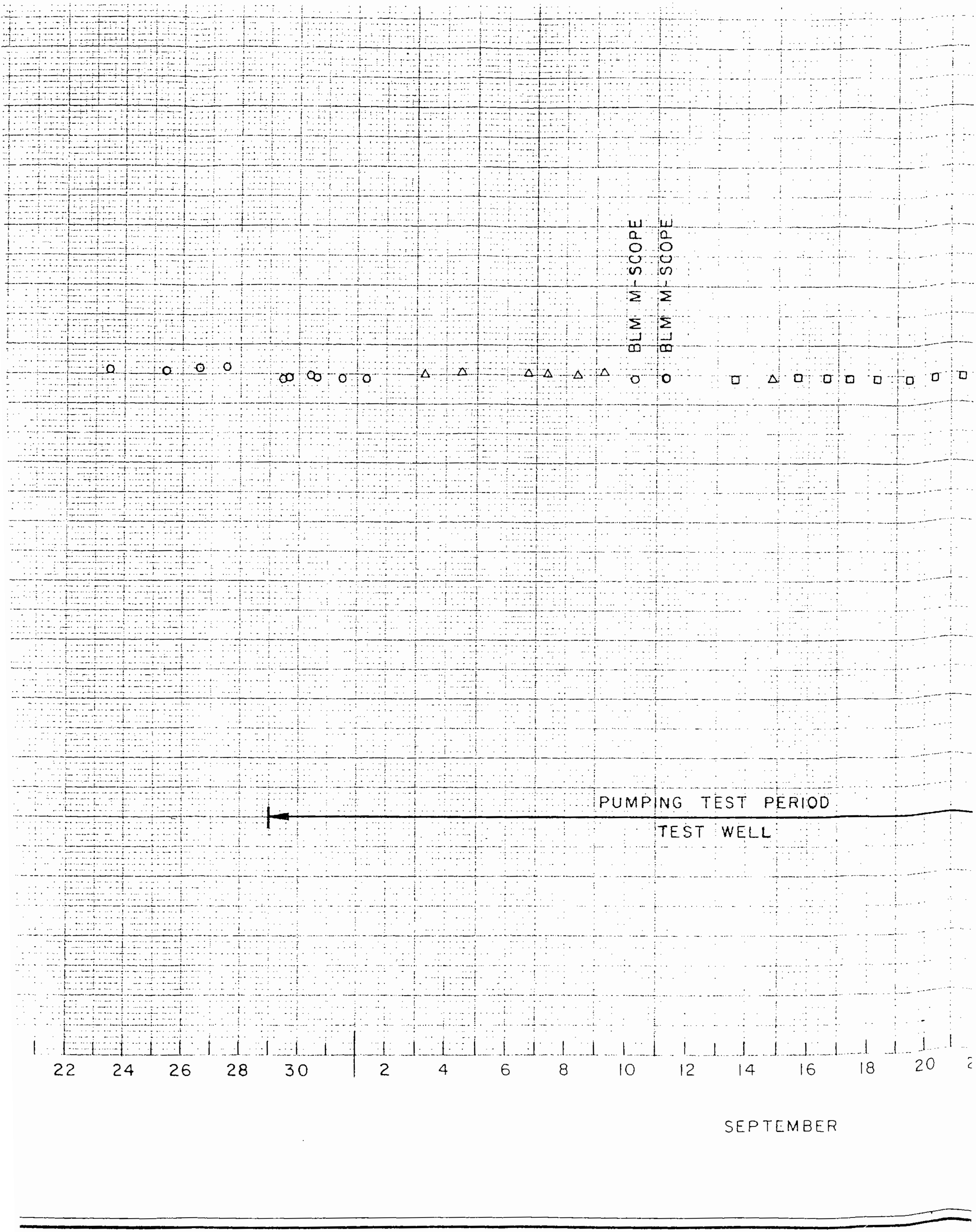
:TOBER

WHITE PINE POWER PROJECT

FOUR POST WELL

NO. STEPTOE VALLEY SITE

FIGURE 3


BLM M-SCOPE
BLM M-SCOPE
PUMPING TEST PERIOD
TEST WELL
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30
2
4
6
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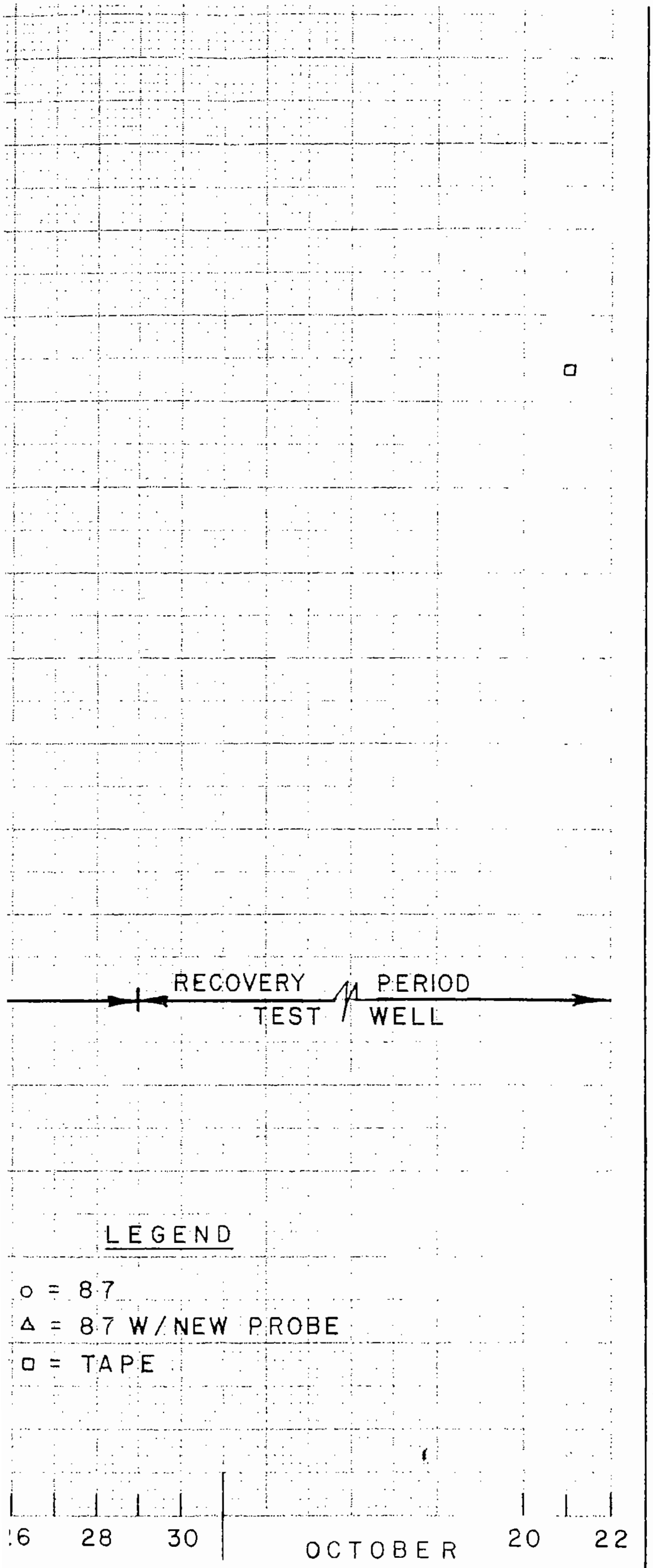
12
14
16
18
20
SEPTEMBER

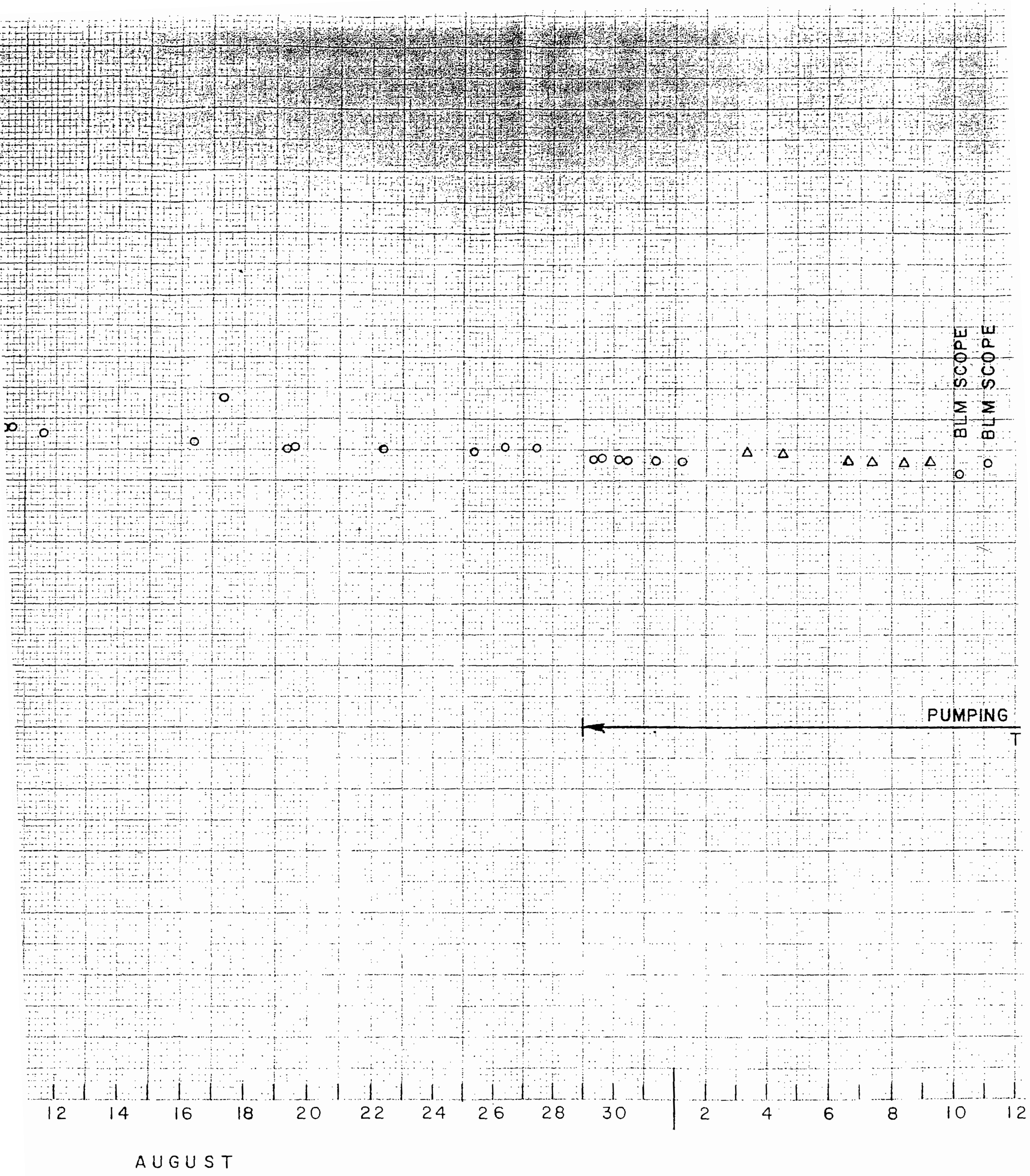


WHITE PINE POWER PROJECT

WELL WW 1796

NO. STEPTOE VALLEY SITE

FIGURE 4


BLM SCOPE
BLM SCOPE
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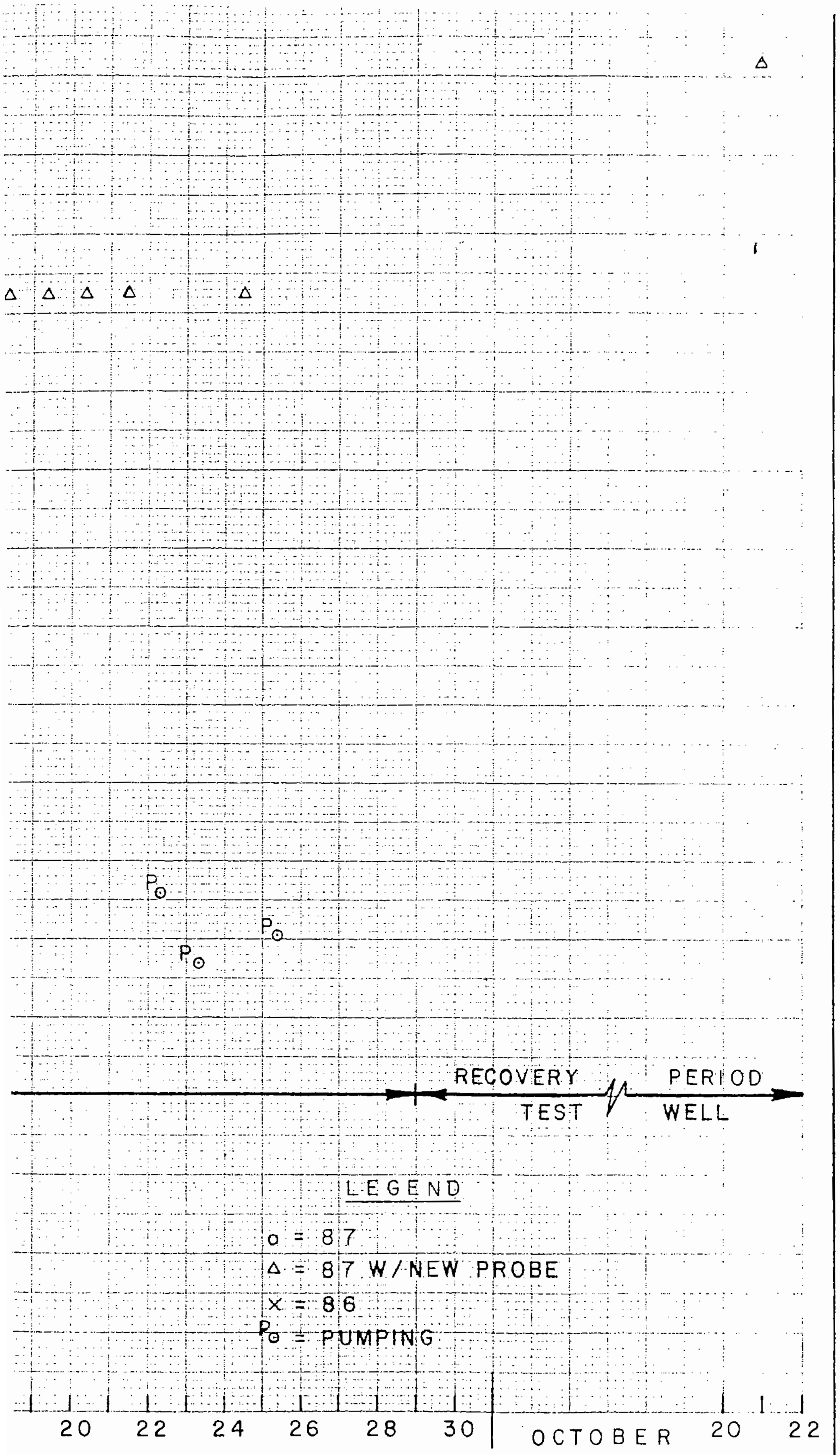
AUGUST

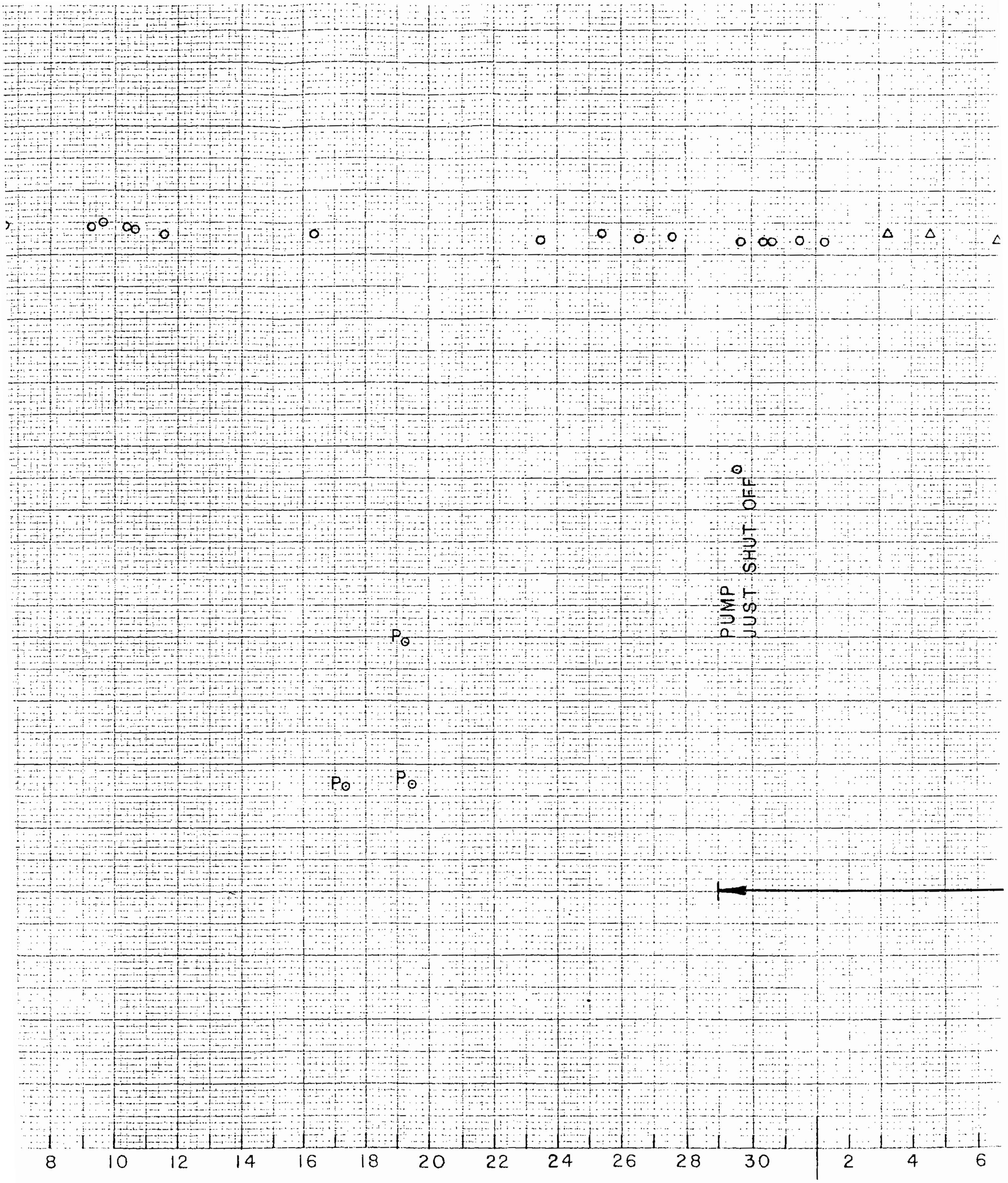


WHITE PINE POWER PROJECT

WELL WM 1796

NO. STEPTOE VALLEY SITE

FIGURE 5


PUMP
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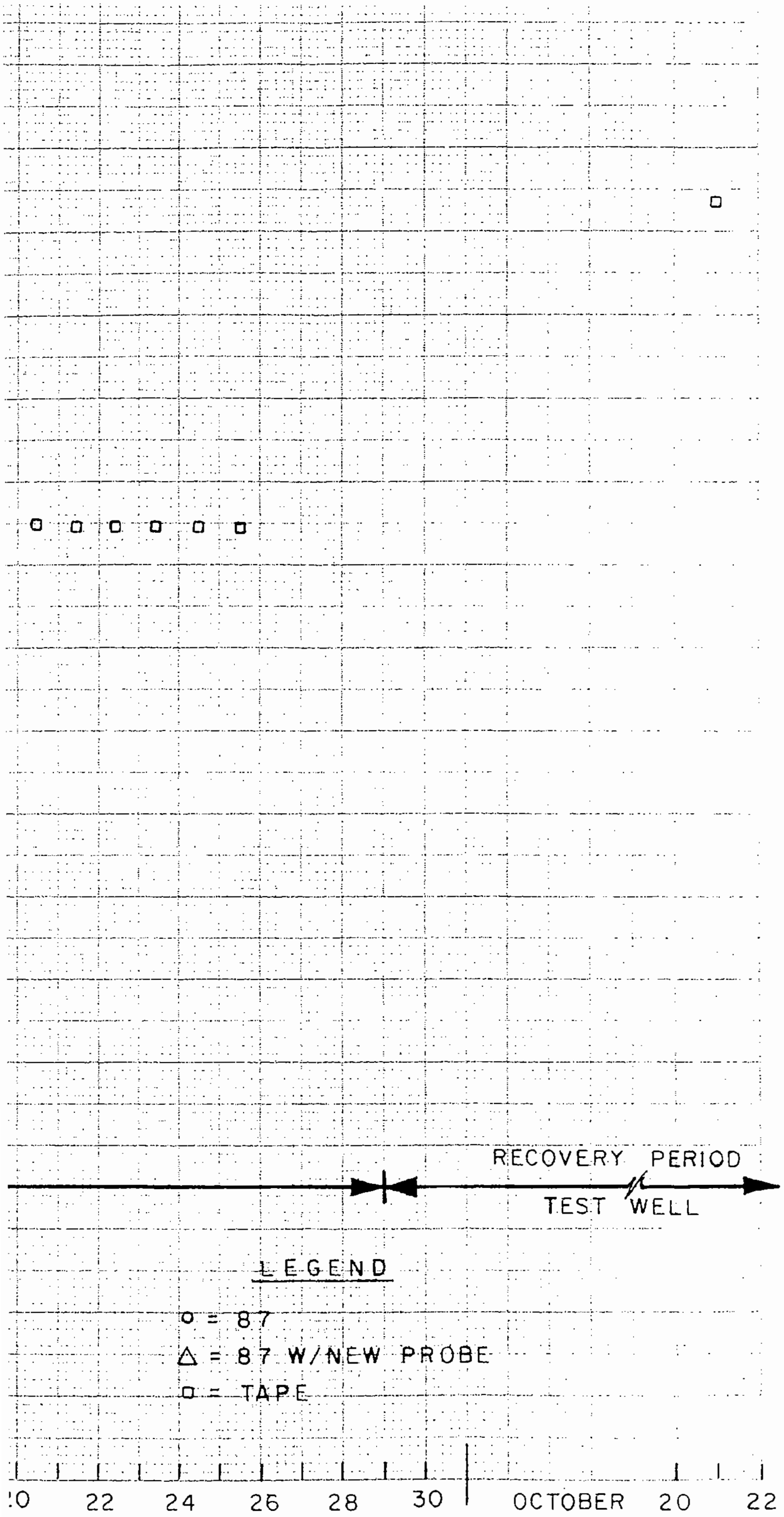
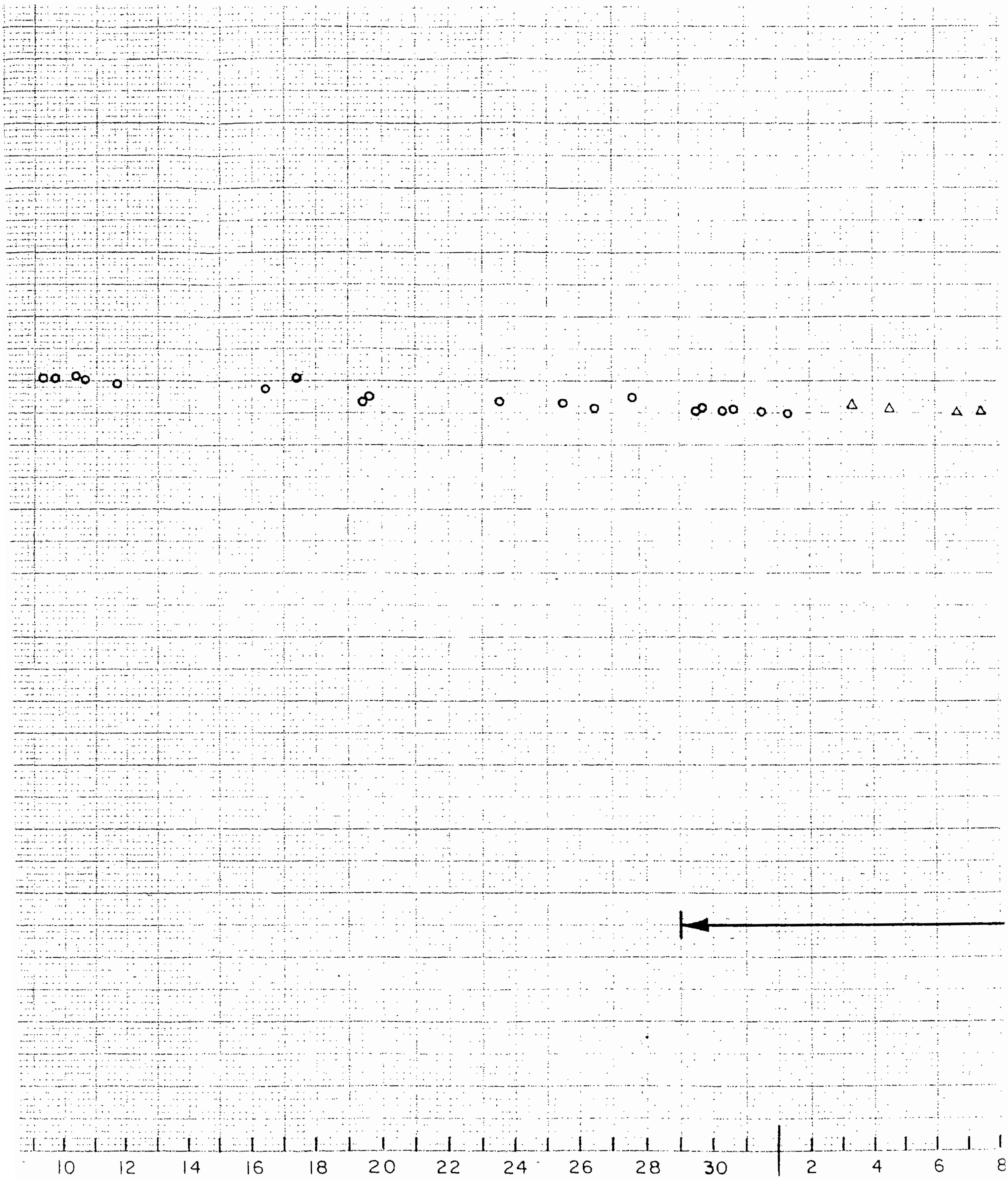
AUGUST

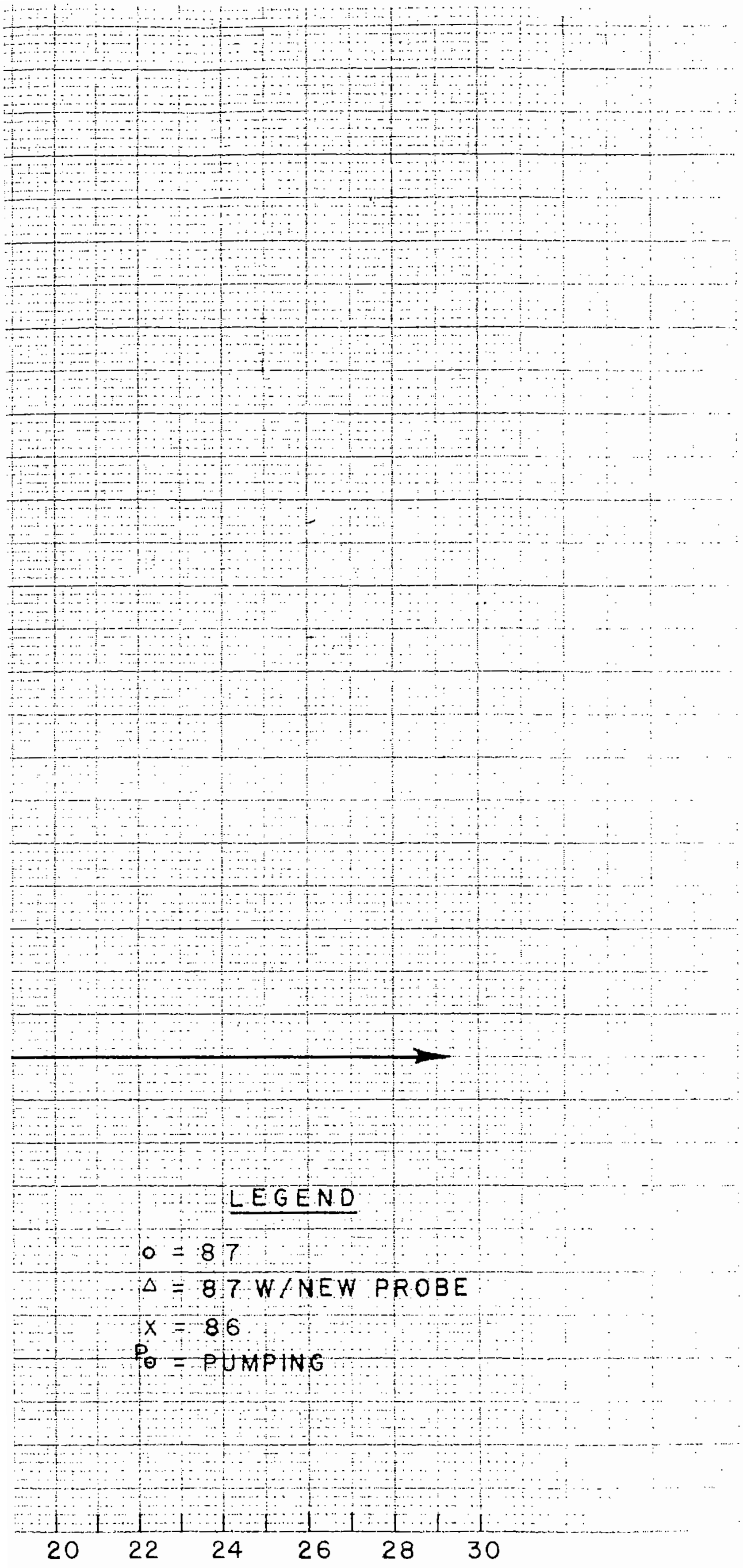


WHITE PINE POWER PROJECT

SALVI WELL (WW1794)
NO. STEPTOE VALLEY SITE
FIGURE 6



AUGUST

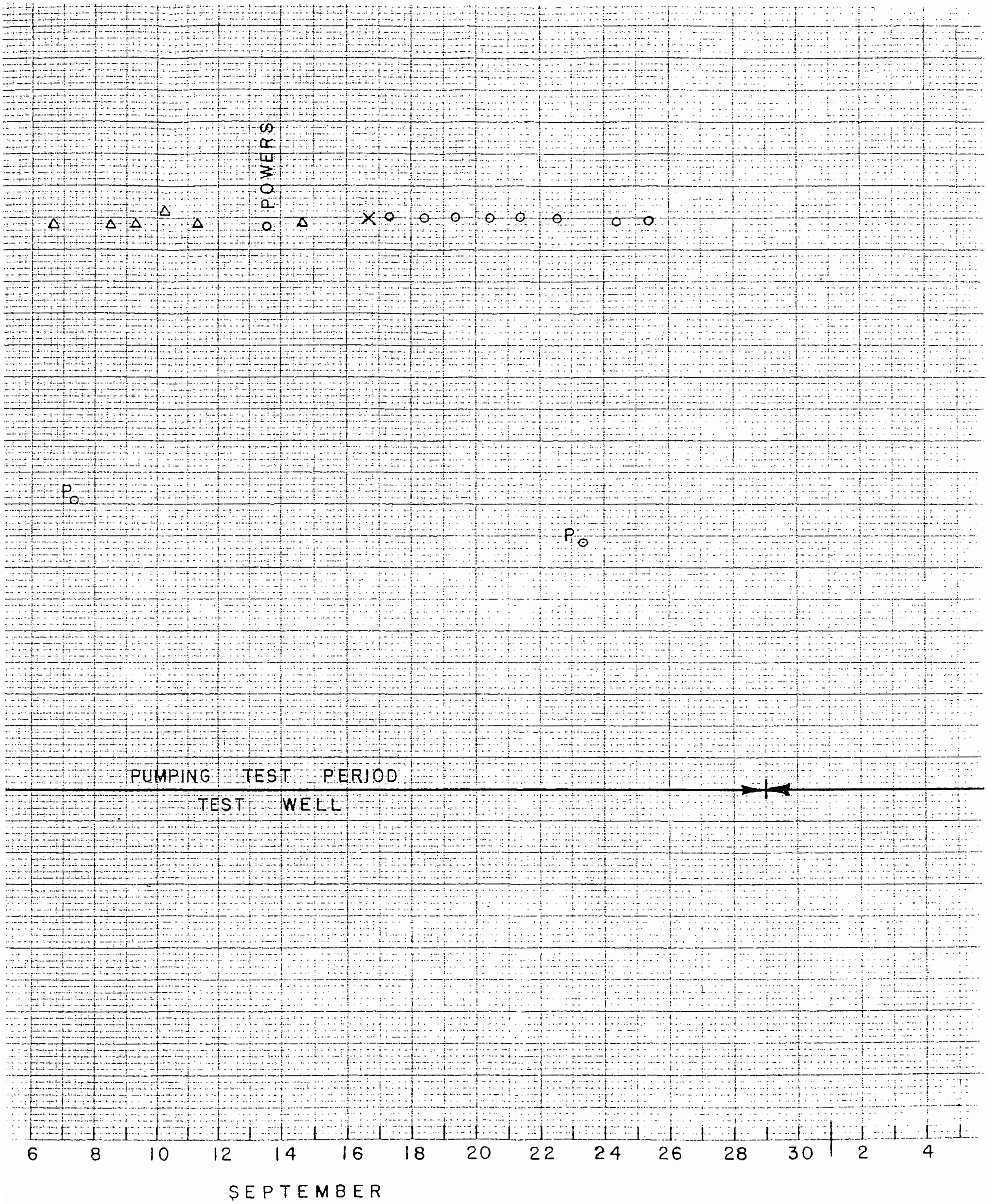


WHITE PINE POWER PROJECT

HILLS BROS. WELL

NO. STEPTOE VALLEY SITE

FIGURE 7


POWERS
P
P
PUMPING TEST PERIOD
TEST WELL
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8
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12
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22
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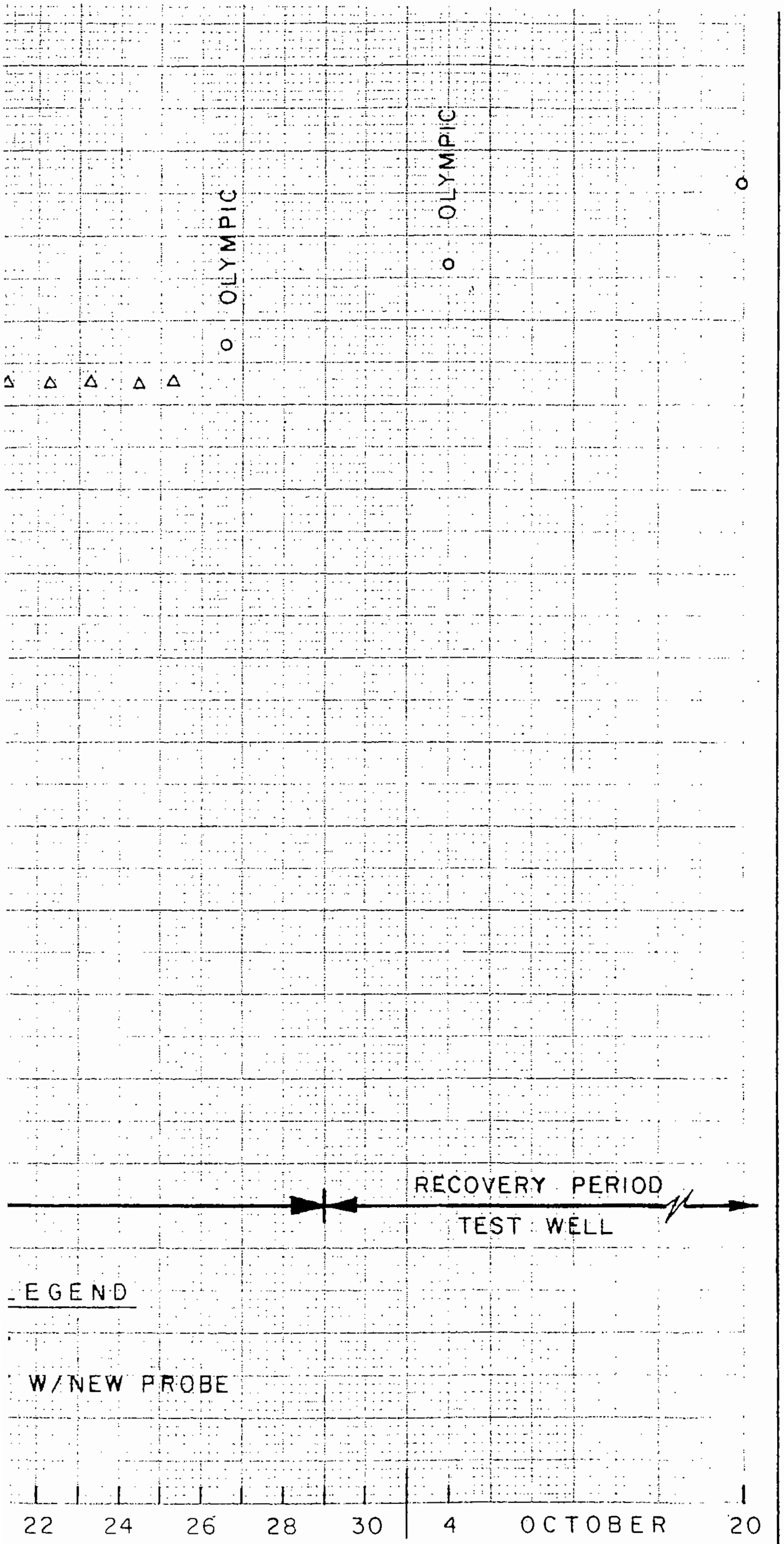
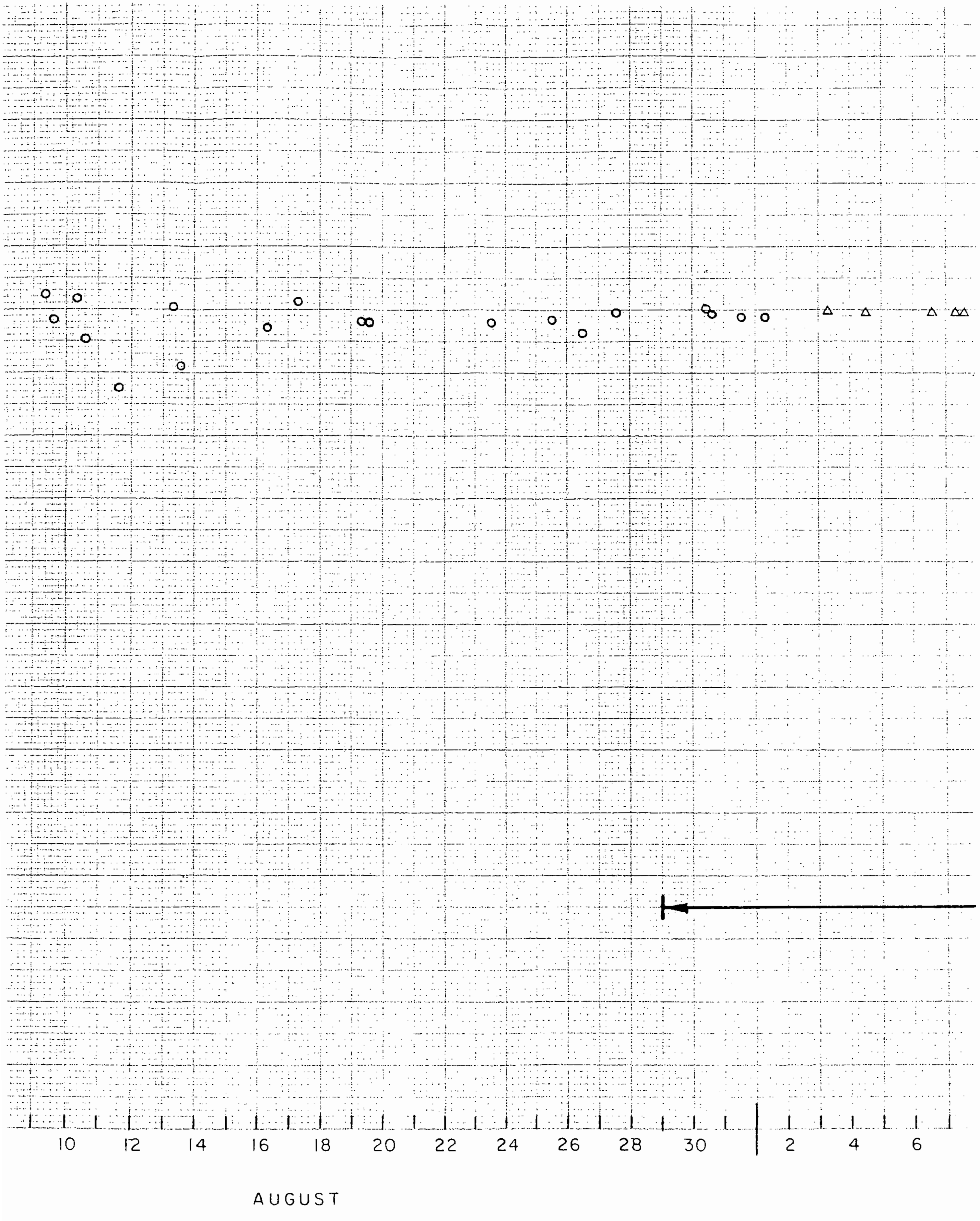
26
28
30
2
4
SEPTEMBER



WHITE PINE POWER PROJECT

STEPTOE VALLEY WINDMILL
NO. STEPTOE VALLEY SITE
FIGURE 8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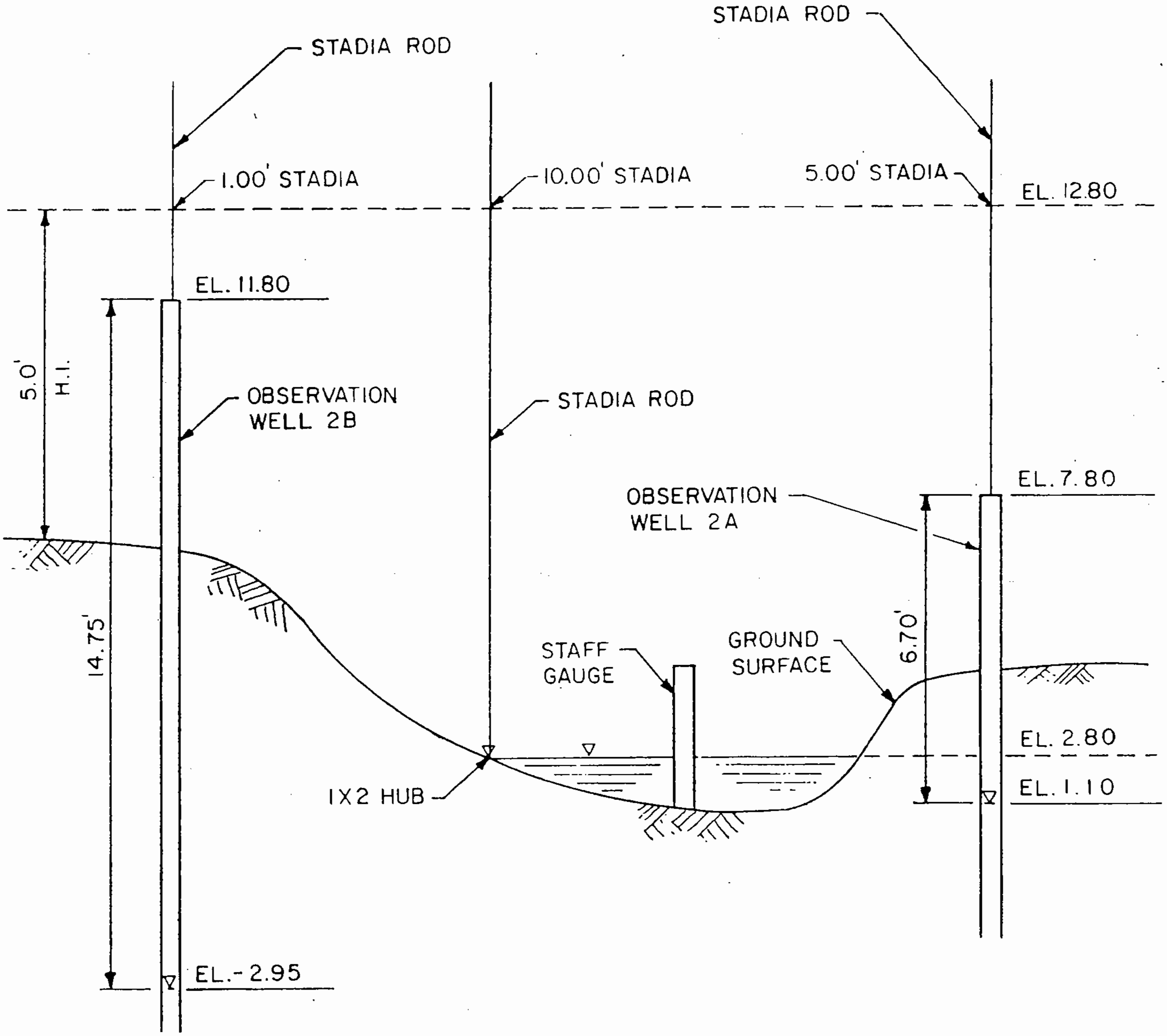
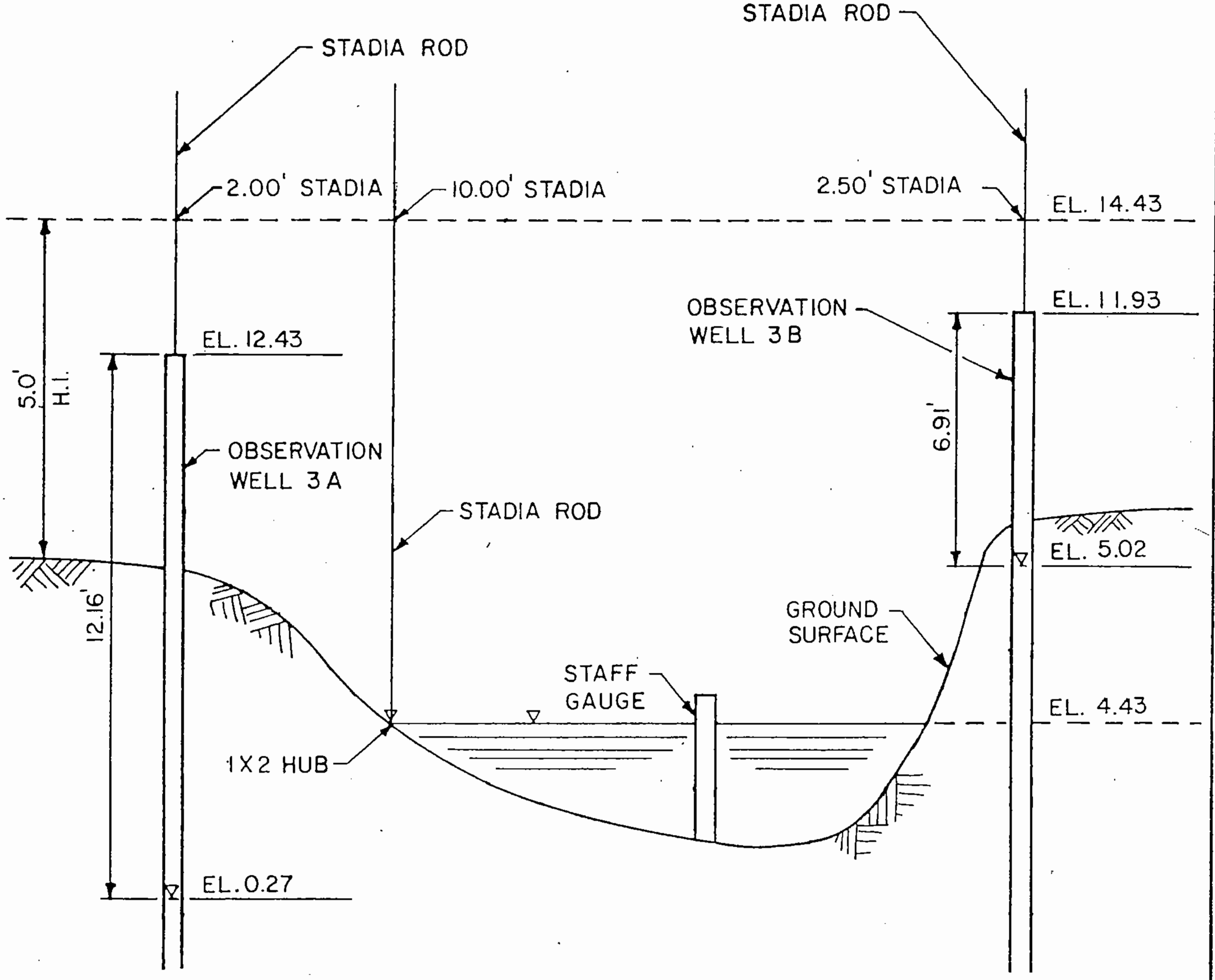


NOTE: ELEVATIONS ARE BASED ON ARBITRARY
DATUM RELATED TO THE STAFF GAUGE.

WHITE PINE POWER PROJECT

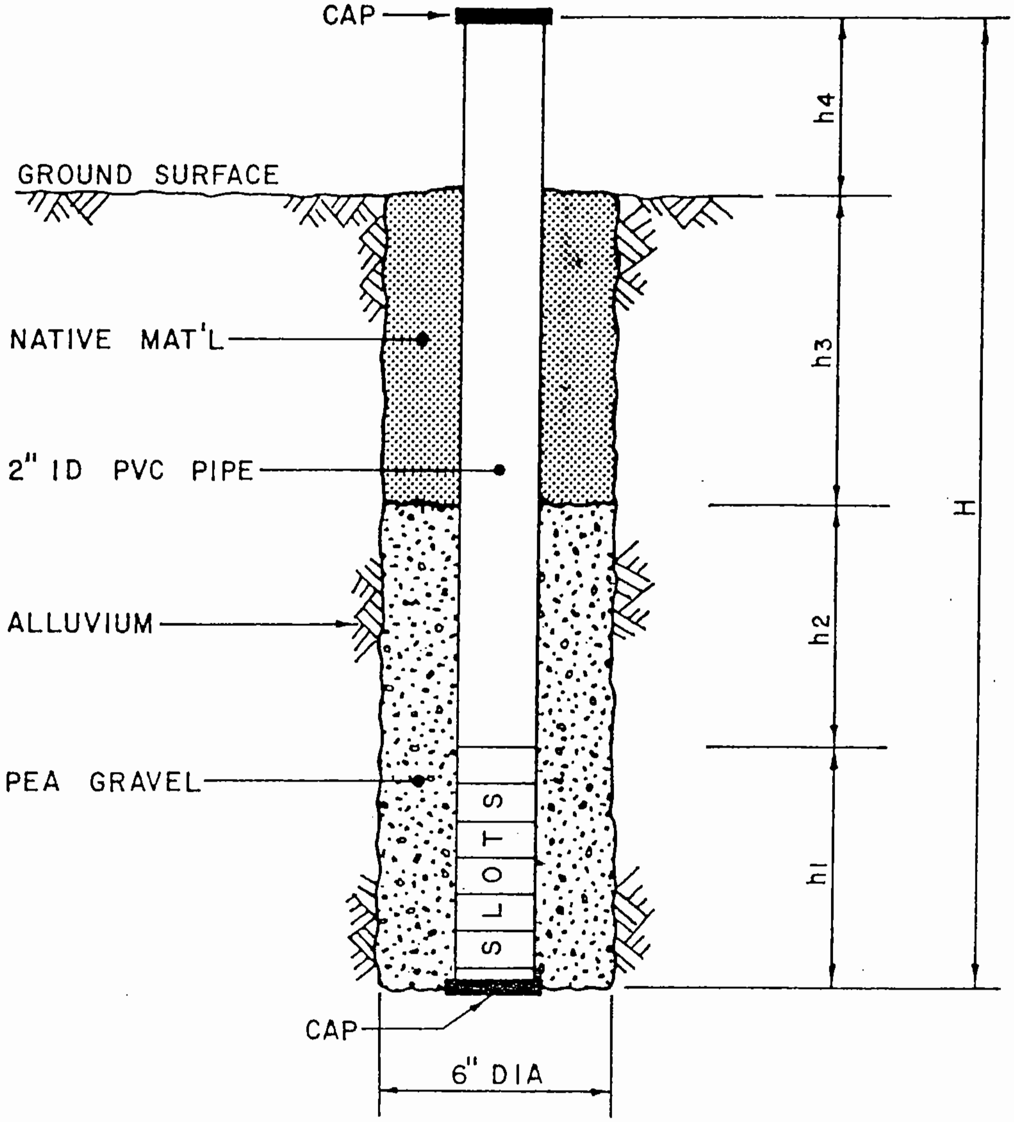
SPRING 2 DATUM RELATIONS
SPRING VALLEY SITE
FIGURE 9



NOTE: ELEVATIONS ARE BASED ON ARBITRARY DATUM RELATED TO THE STAFF GAUGE.

WHITE PINE POWER PROJECT

SPRING 3 DATUM RELATIONS
SPRING VALLEY SITE
FIGURE 10



OBSERVATION WELL MEASUREMENTS

	1	2A	2B	3A
H	14.0'	20.3'	20.2'	14.0'
h1	5.0'	5.0'	2.0'	5.0'
h2	2.0'	5.0'	12.1'	2.0'
h3	4.0'	6.6'	2.5'	4.0'
h4	3.0'	3.7'	3.6'	3.0'

NOTE:

WELL 3B IS CONSTRUCTED SIMILAR TO WELL 3A BUT NOT RECORDED.

WHITE PINE POWER PROJECT

OBSERVATION WELL DETAIL
SPRING VALLEY SITE
FIGURE 11

WPPP-Spring Valley
Well Log - Spring No. 1
Observation Well 1
Figure 12

Depth	Description
0-1 1/2'	Light brown clay, silty sand, medium dense, minor gravel, minor roots.
1 1/2-9'	Grey blue sandy clay, minor gravel, medium soft, very moist.
9-10'	Brown silty clay, medium soft, very moist.
10-11'	Color to red brown.

5'	Perforated slots
7'	Pea gravel from 11-4'
4'	Native material 4'-surface
37.5" (3.125')	Casing above ground.

WPPP - Spring Valley
Well Log - Spring No. 2
Observation Well 2A
Figure 13

Depth	Description
0-4'	Light brown fine silty sand, red, dense, slightly moist to moist, small roots and gravel.
4-7'	Grey blue clayey sand, medium dense, moist. Moisture increasing with depth.
7-16 1/2'	Green clayey sand, medium dense, moist.
16 1/2'	Red brown gravelly clayey sand.

5'	Perforated slots
10'	Pea gravel from 16.6-6.6'
6.6	Native material 6.6'-surface
3' 8 1/2" (3.71')	Casing above ground

WPPP - Spring Valley
Well Log - Spring No. 3
Observation Well 3A
Figure 14

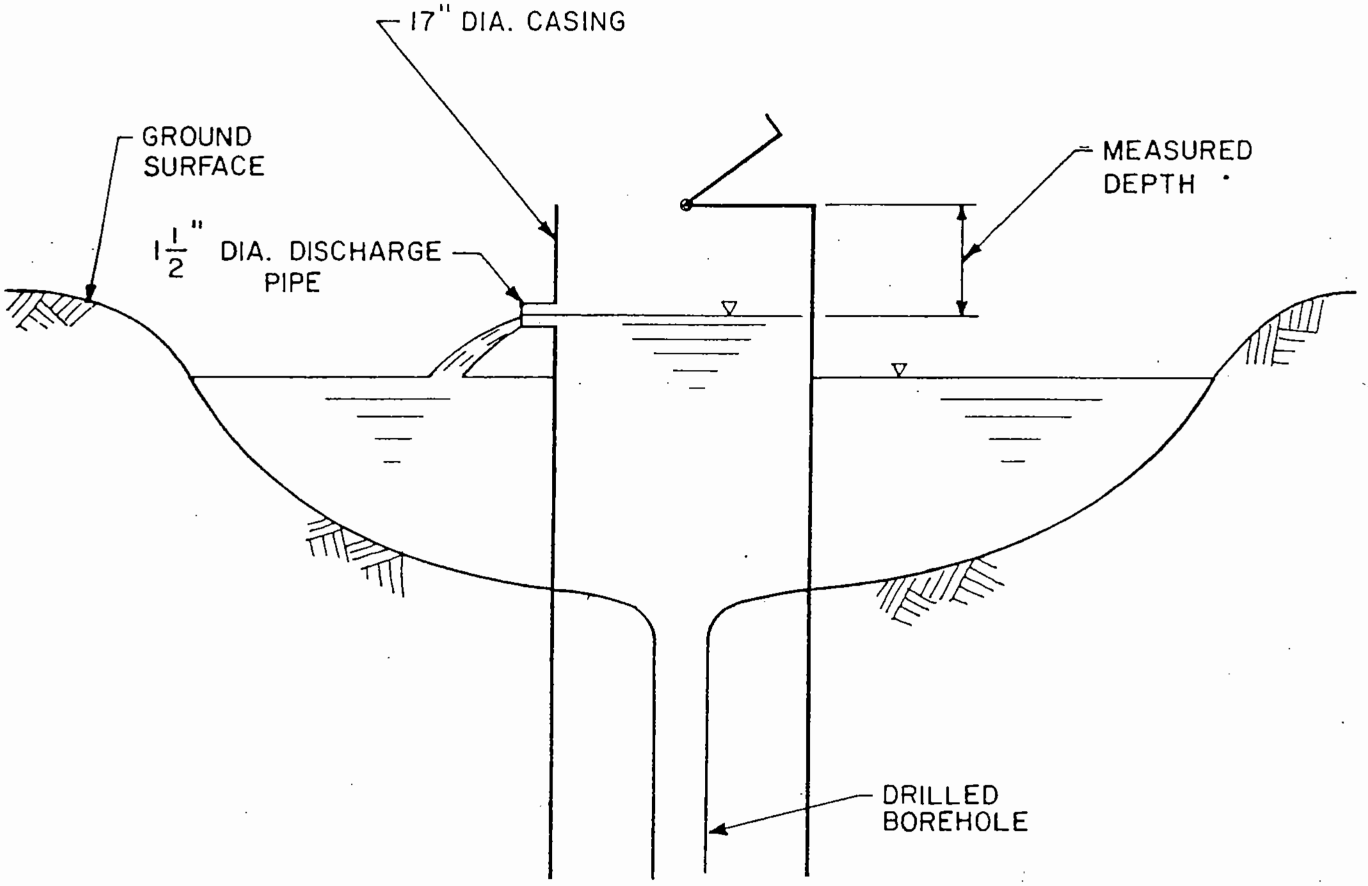
Depth	Description
0-7'	Light brown medium sand, dense and moist. Becomes more moist with depth.
7-10'	Slightly clayey dark and light brown mottled sand.
10-11'	Mottled green and brown clay.
11'	Mottled green and blue clay.

5'	Performations
7'	Pea gravel from 11-4'
4'	Native material 4'-surface
34.5" (2.875')	Casing above ground

WPPP - Spring Valley
Well Log - Spring No. 3
Observation Well 3B
Figure 15

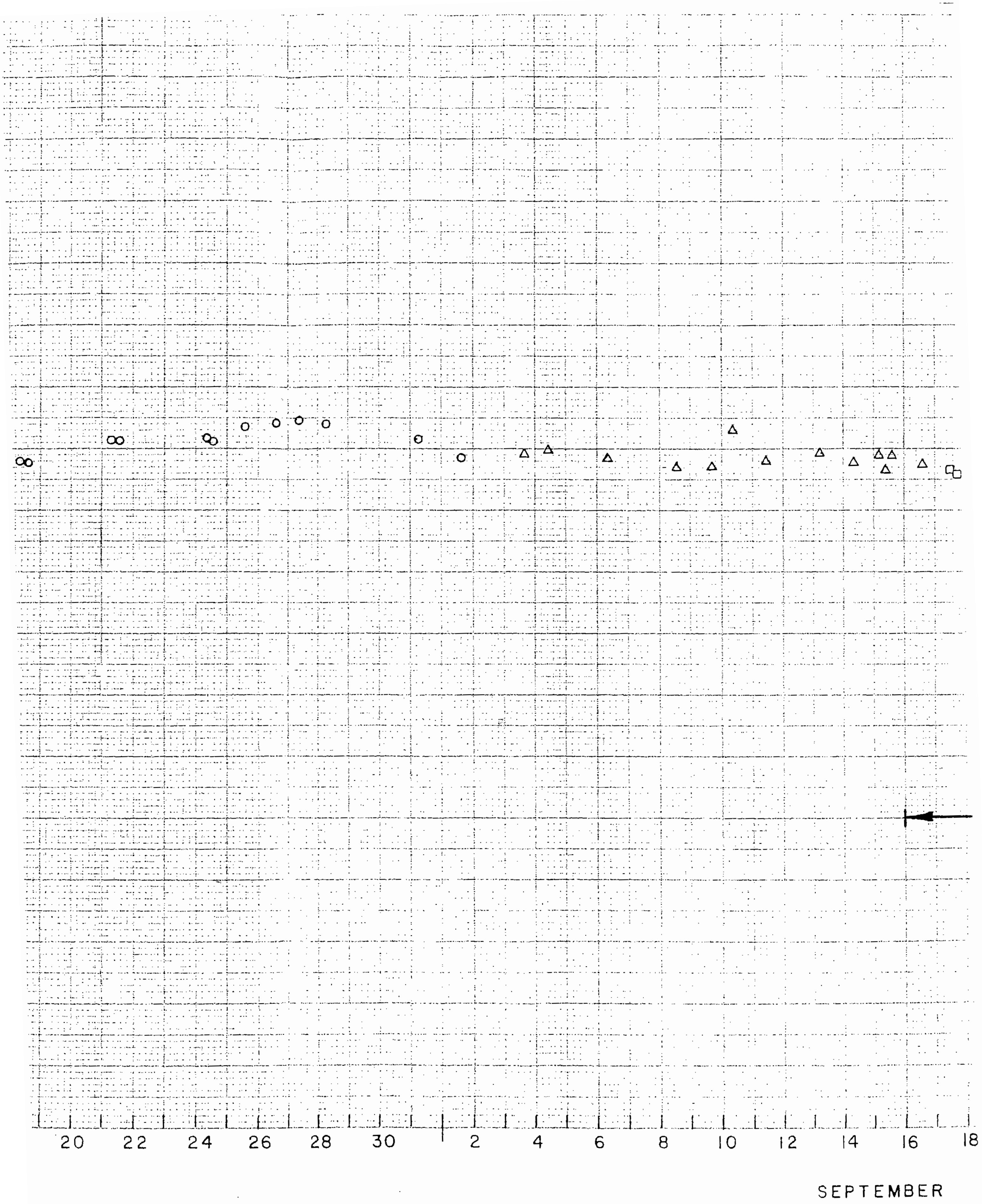
Depth	Description
0-2'	Dark brown, slightly damp silty clay containing abundant organic material.
2-4'	Very dark brown to black, damp to moist slightly silty clay containing organic material, plastic.
4-6'	Very dark grey brown to brown moist to wet, slightly silty clay containing organic material, plastic, slightly sandy at bottom.
6-8'	Dark grey brown grading to dark grey, wet, silty sandy clay grading to clayey silty sand. Sand is fine to medium grained, predominantly medium grained, well sorted, subangular.
8-9'	Dark grey grading to dark green wet silty sandy clay grading to clay.

2'	Perforated slots
7 1/2'	Pea gravel 9-1 1/2'
1 1/2'	Native material 1 1/2'-surface
39.84" (3.32)	Casing above surface



WHITE PINE POWER PROJECT

SPRINGS 4 AND 5
CASING WITH DISCHARGE
SPRING VALLEY SITE
FIGURE 16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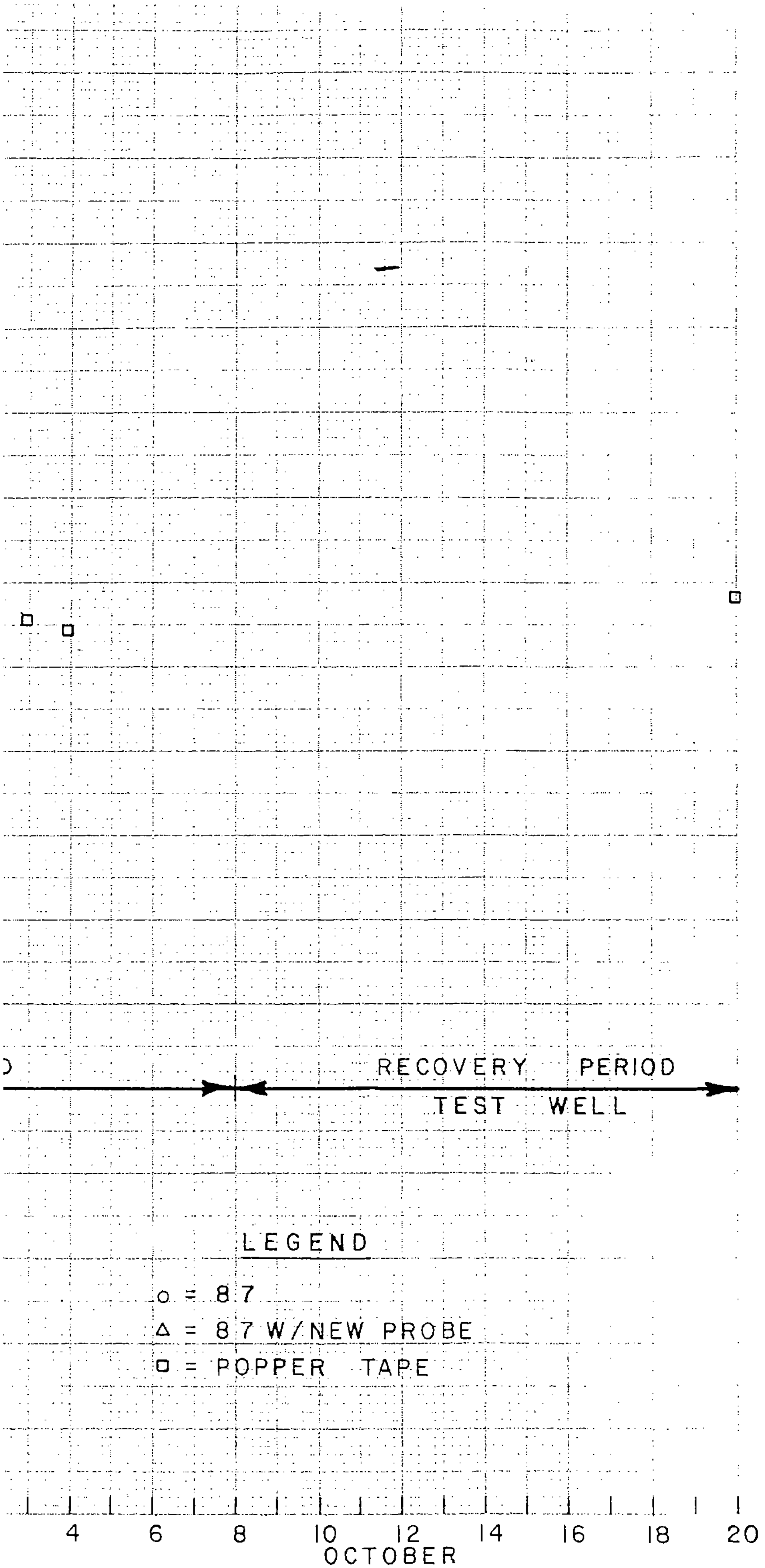
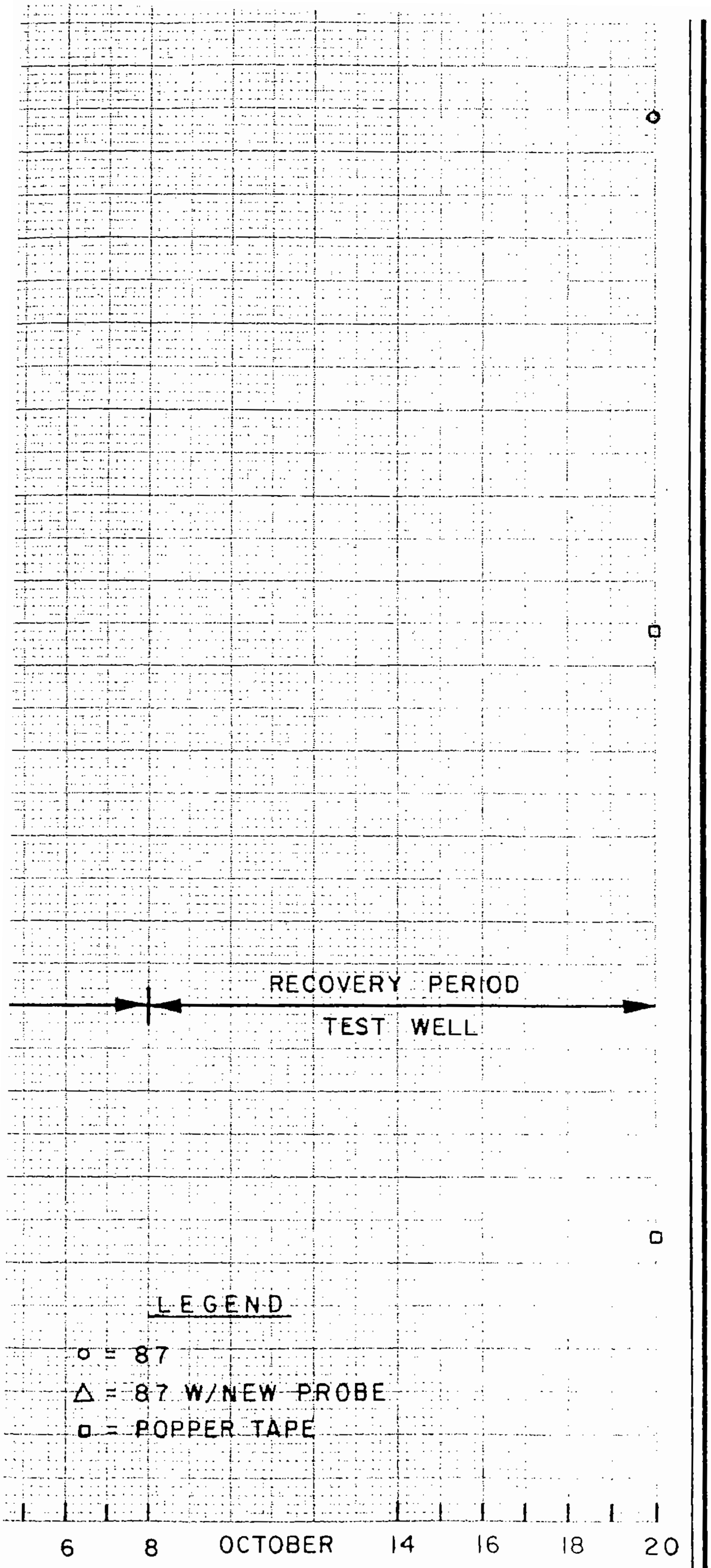


WHITE PINE POWER PROJECT

SPRING I

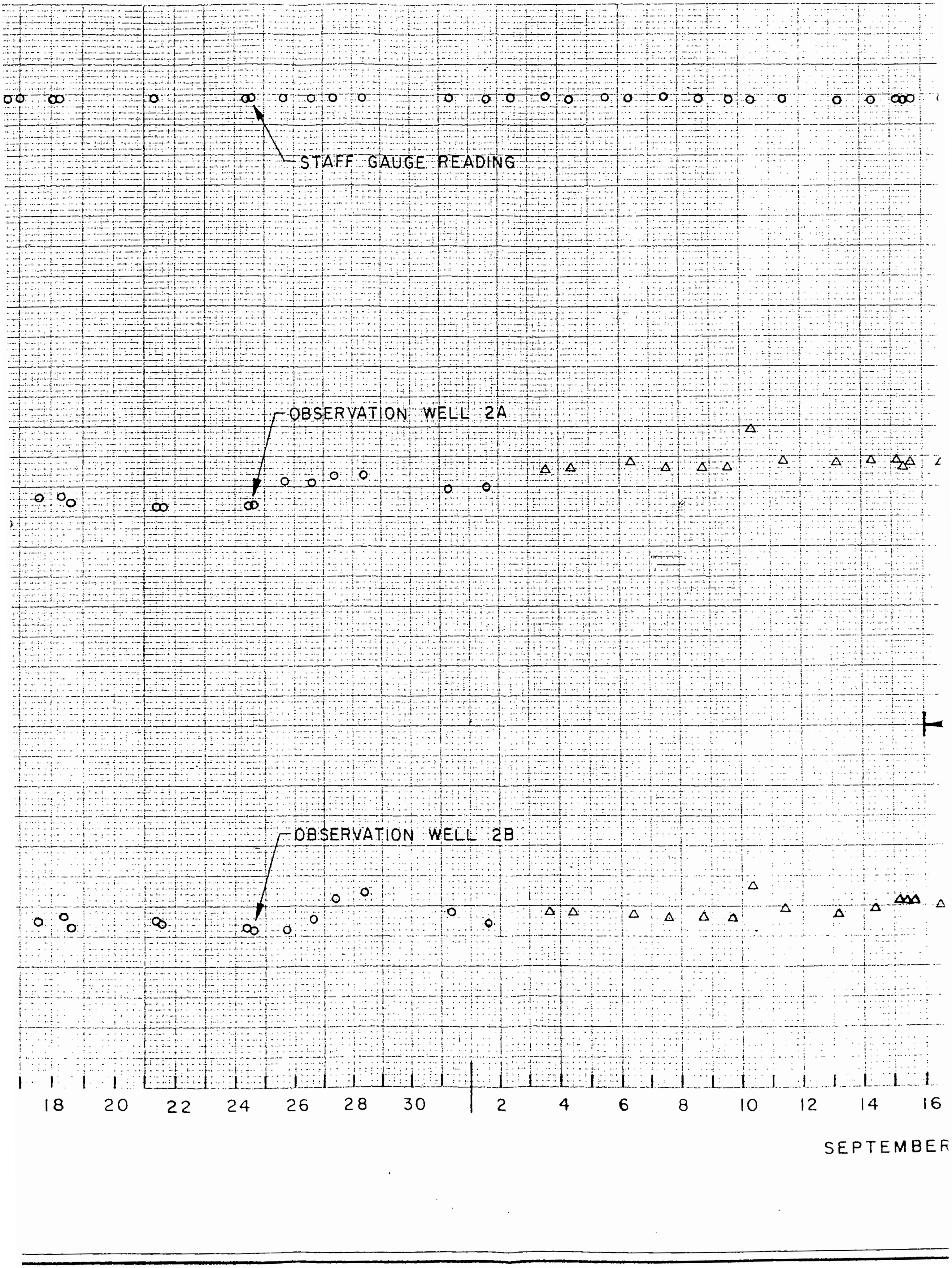
SPRING VALLEY SITE

FIGURE 17



WHITE PINE POWER PROJECT

SPRING 2
STAFF GAUGE & OBSERVATION WELLS 2A & 2B
SPRING VALLEY SITE
FIGURE 18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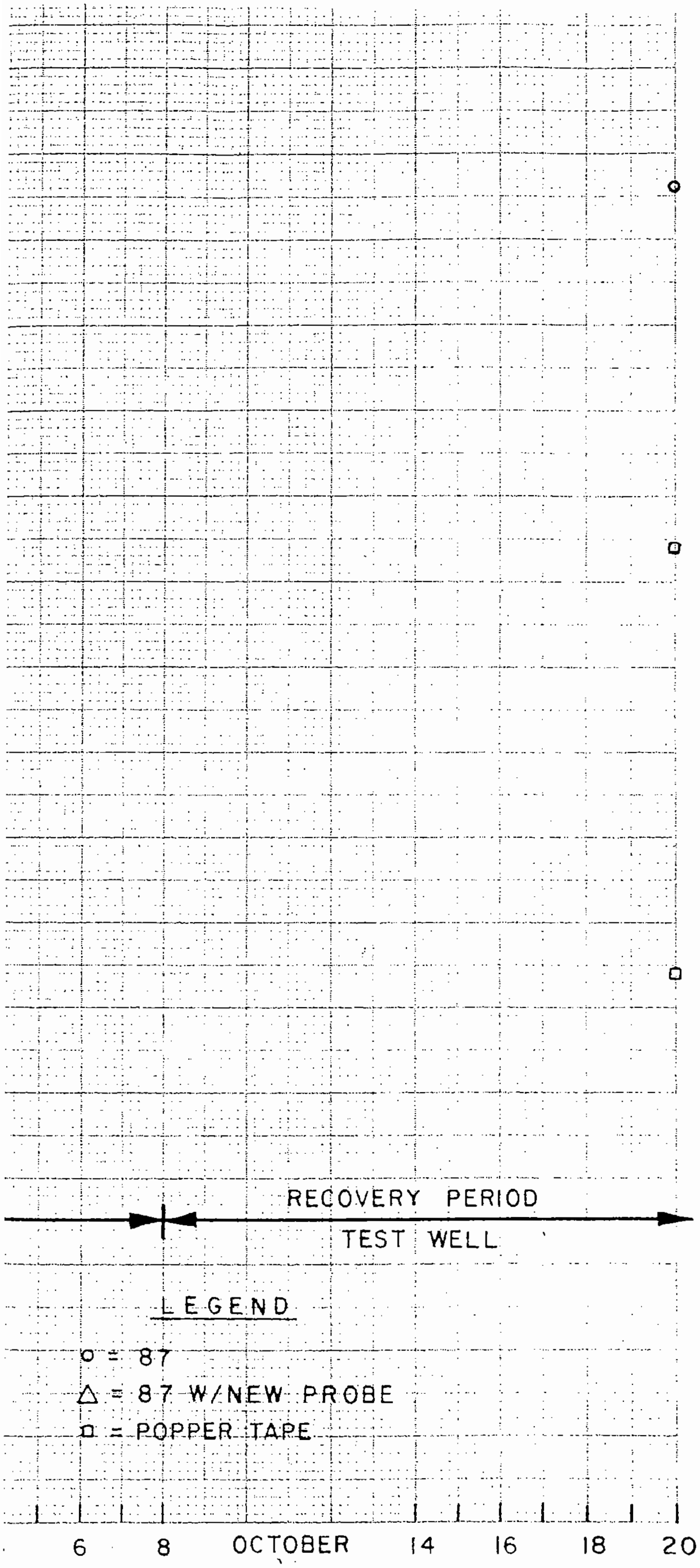
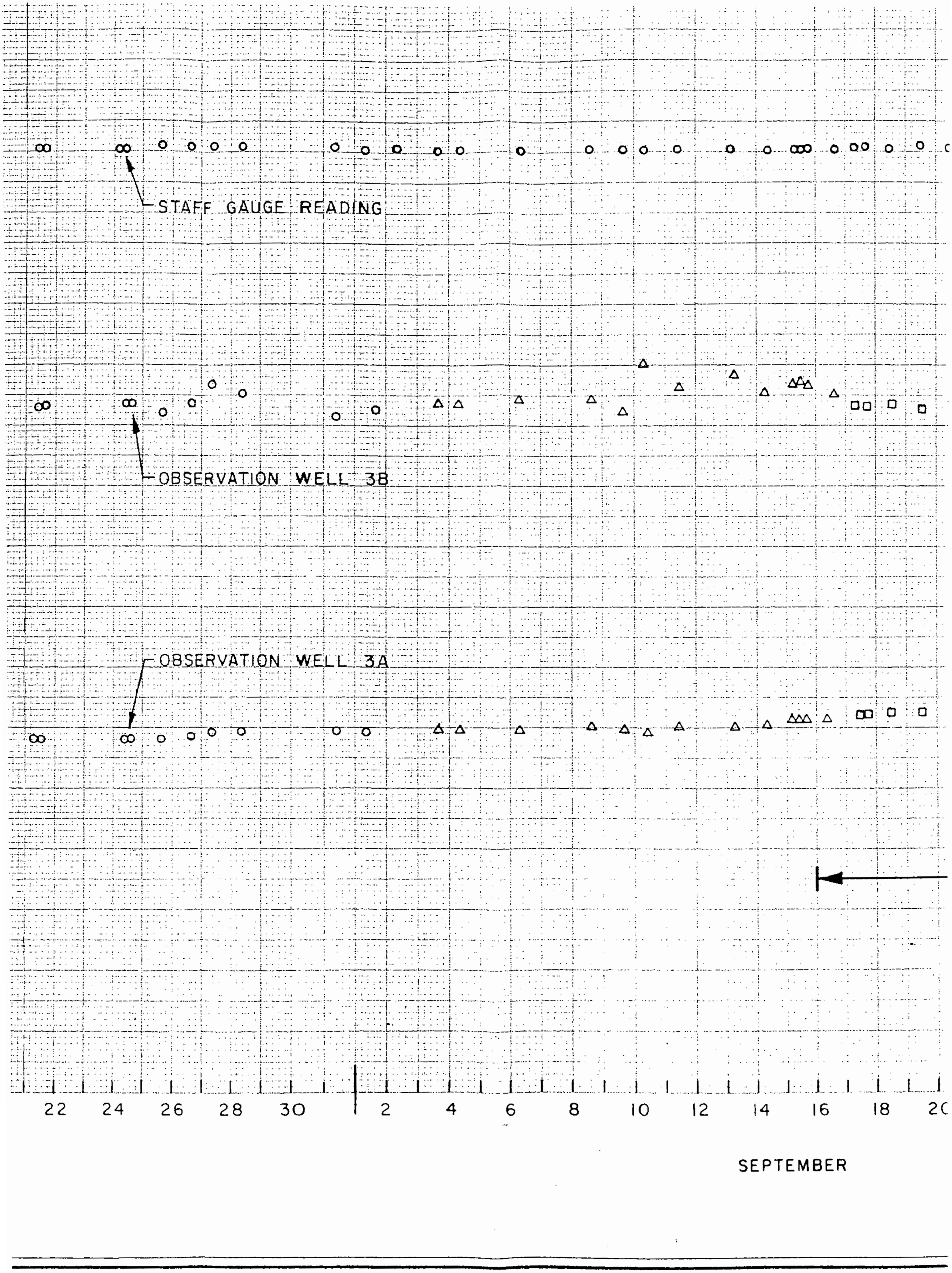


WHITE PINE POWER PROJECT

SPRING 3
STAFF GAUGE & OBSERVATION WELLS 3A & 3B
SPRING VALLEY SITE
FIGURE 19


STAFF GAUGE READING
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OBSERVATION WELL 3A
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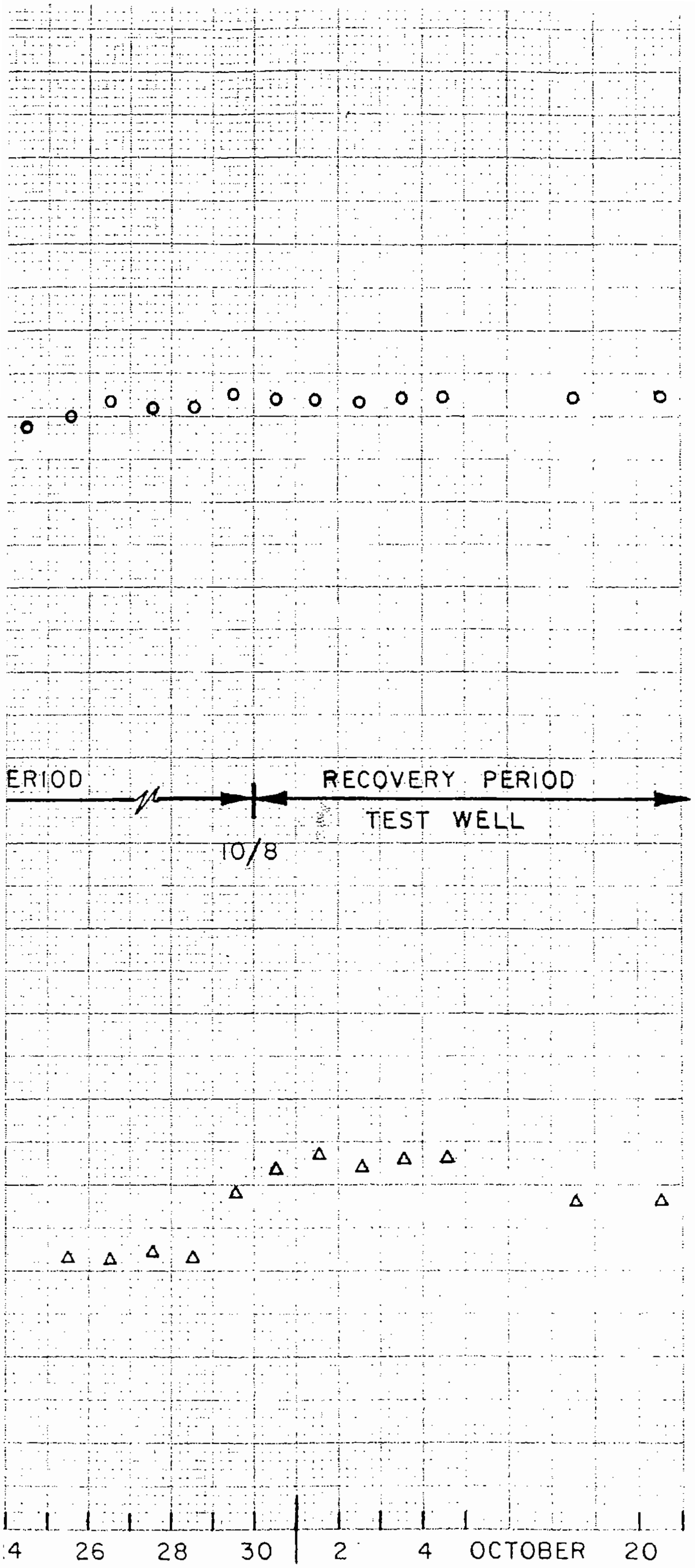
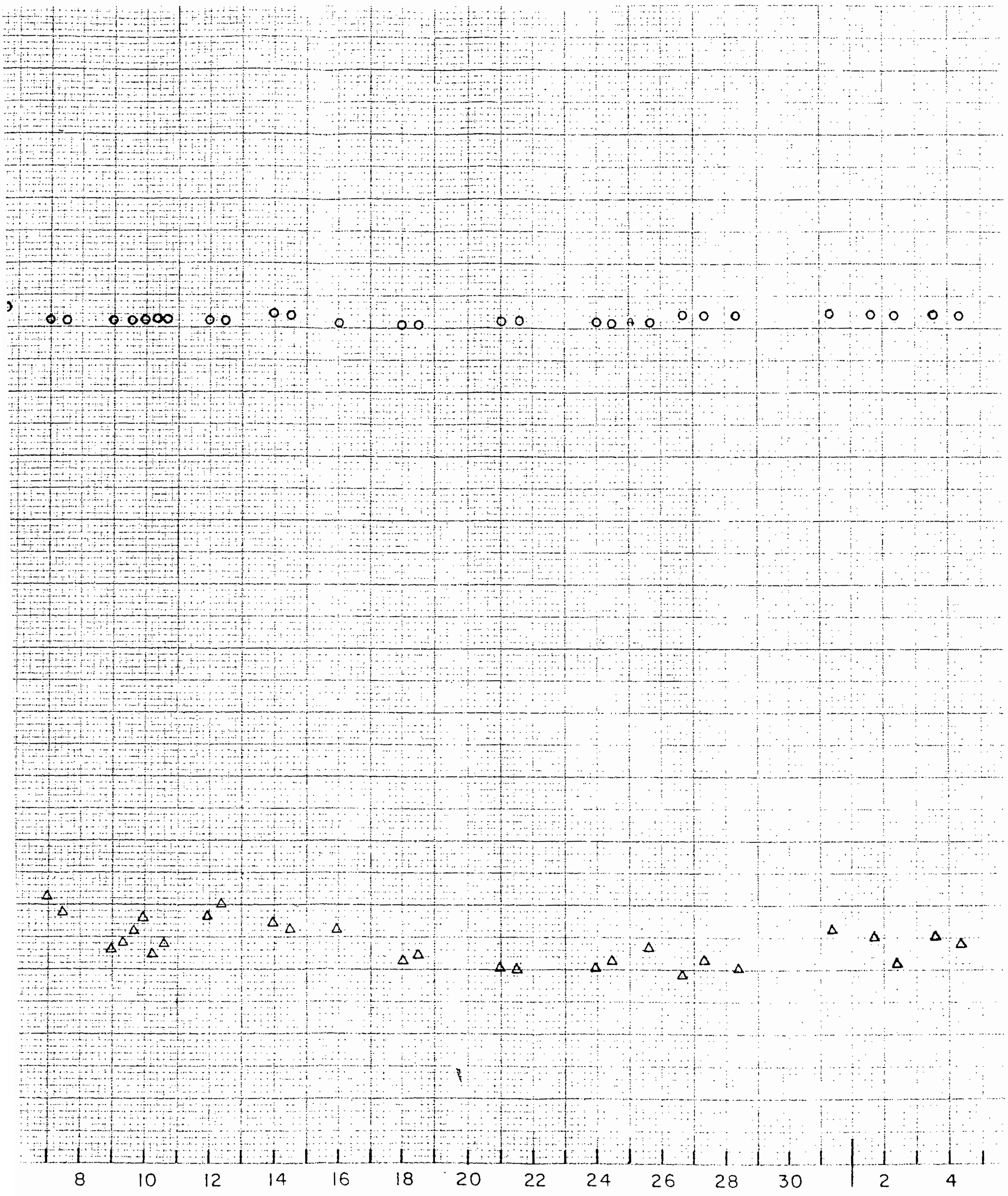


WHITE PINE POWER PROJECT

SPRING 4
SPRING VALLEY SITE
FIGURE 20



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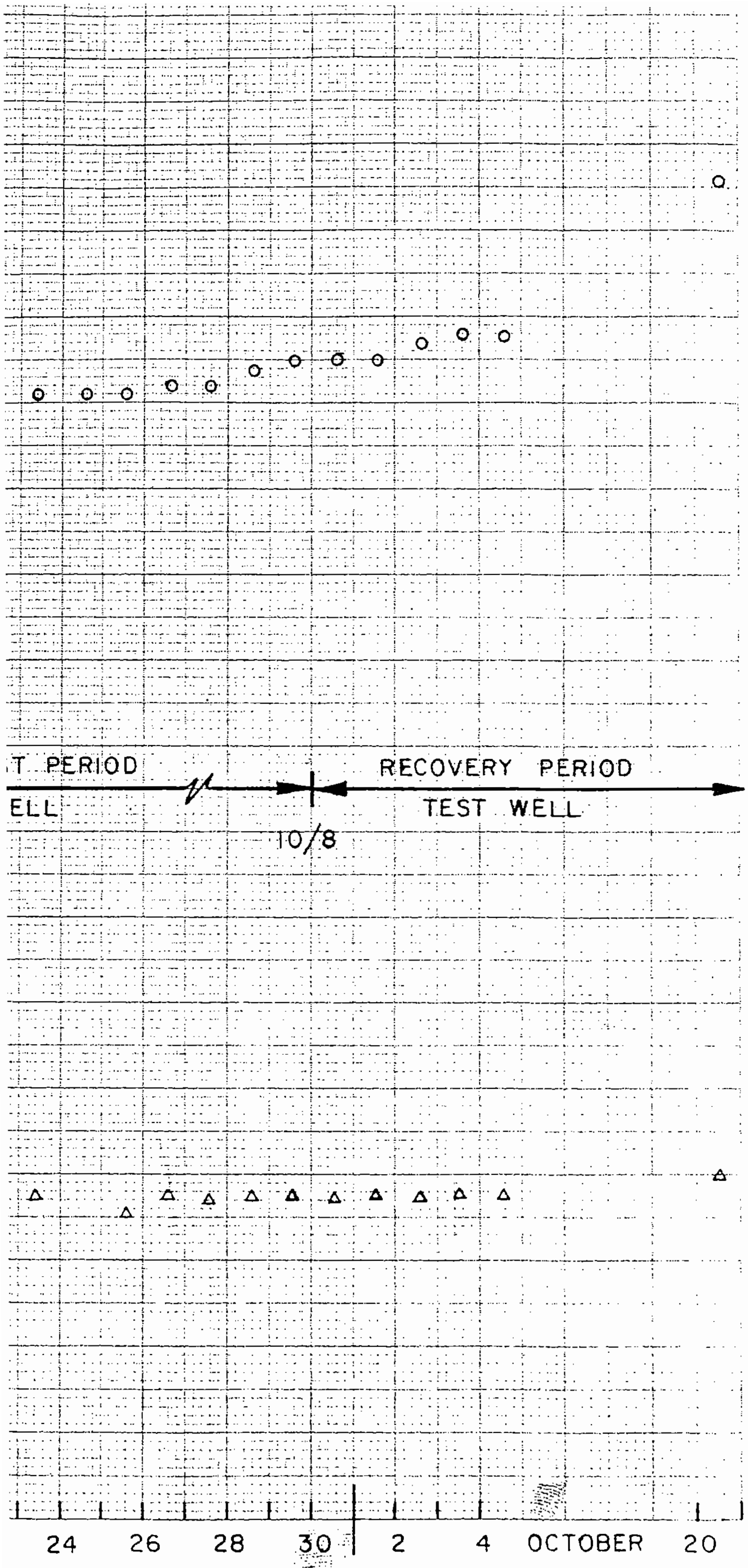
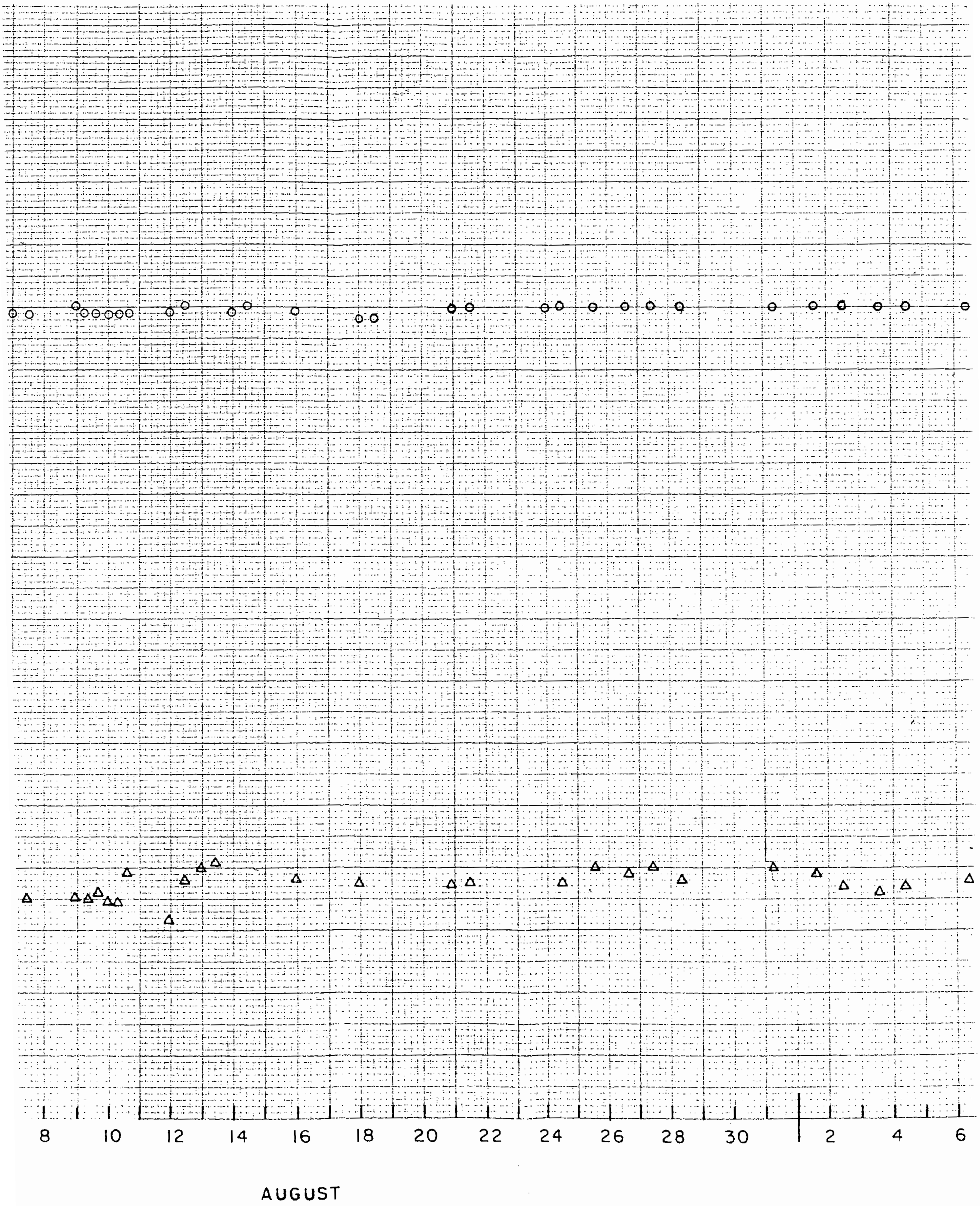


WHITE PINE POWER PROJECT

SPRING 5
SPRING VALLEY SITE
FIGURE 21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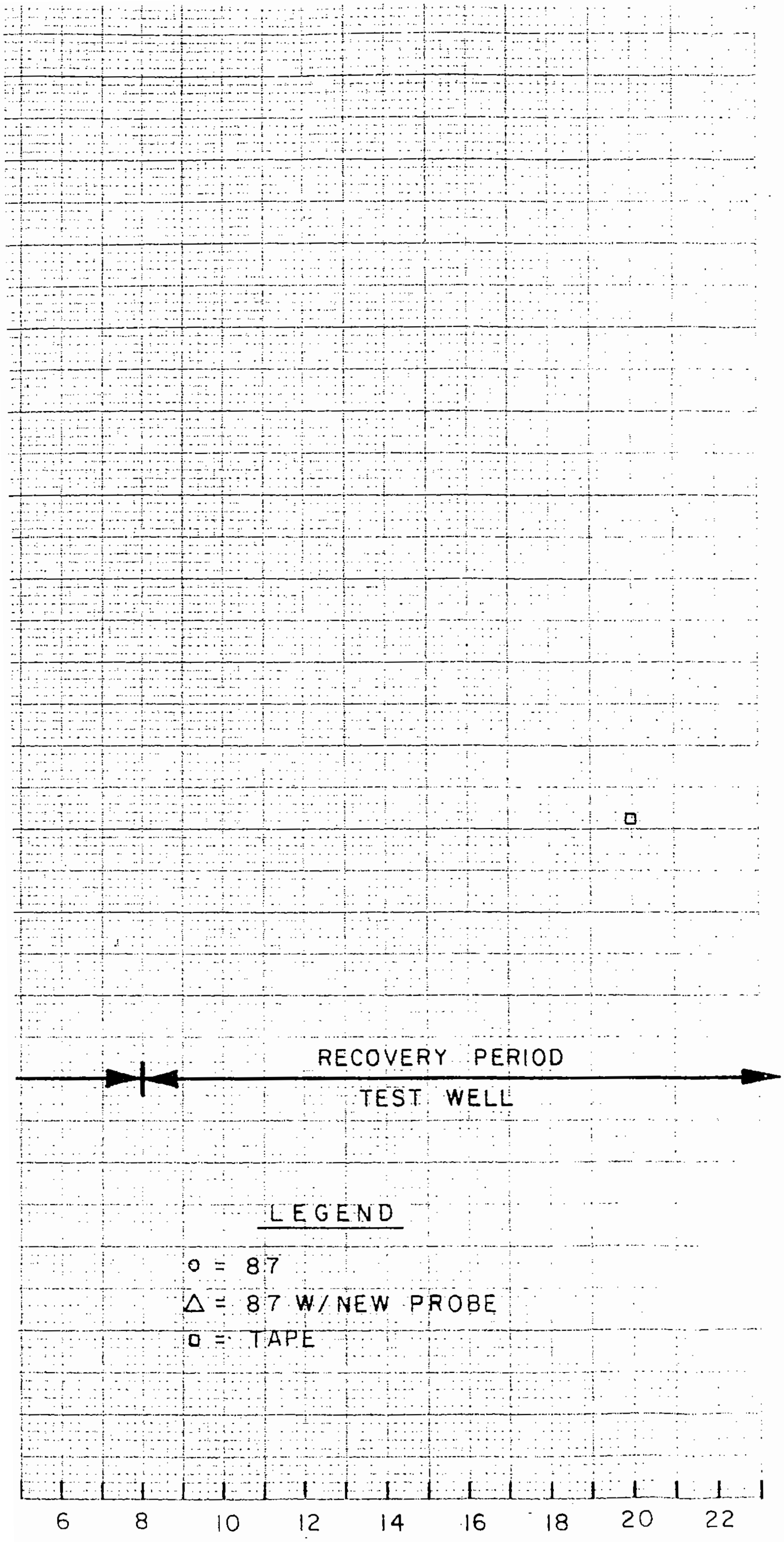

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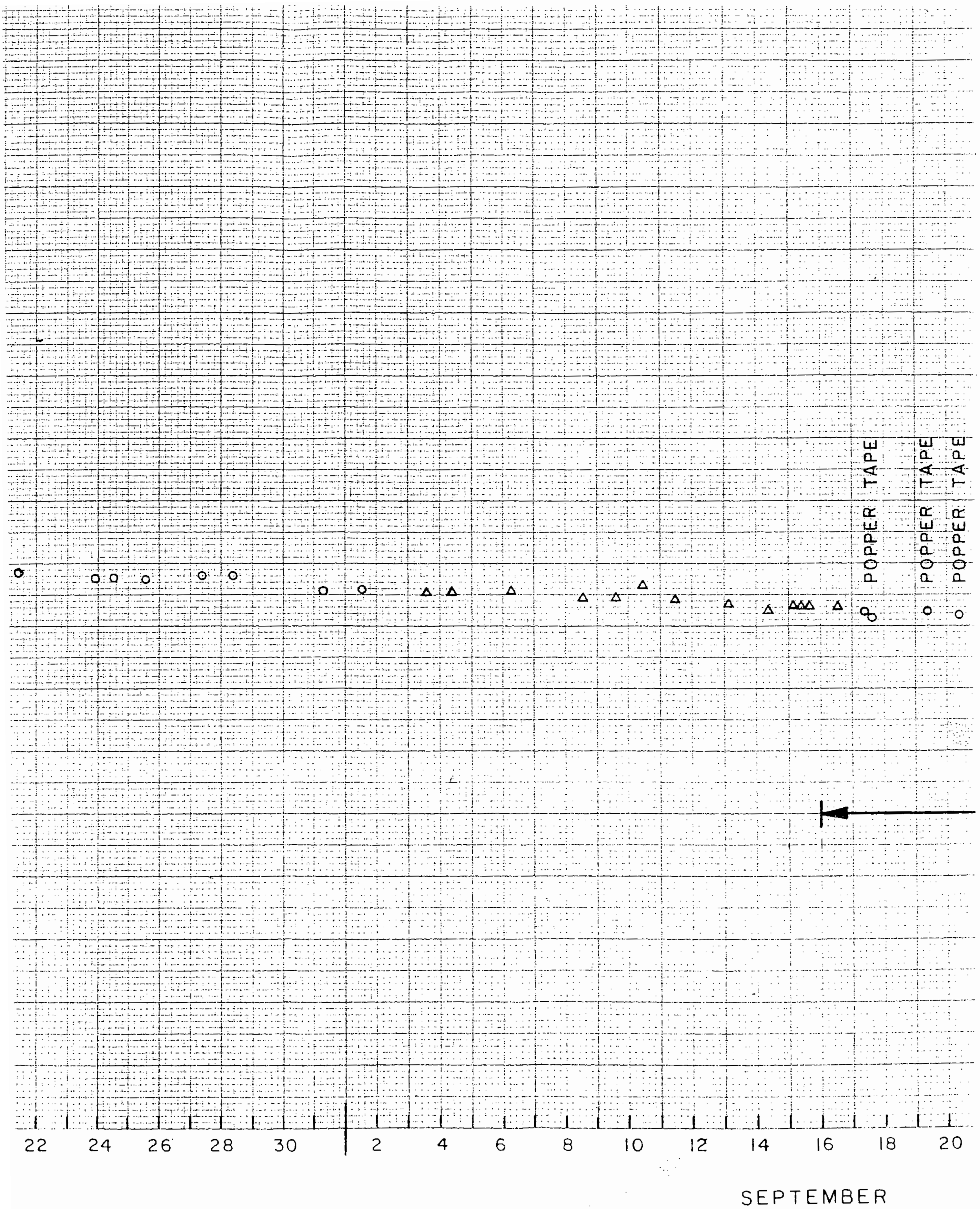
WHITE PINE POWER PROJECT

TEJON RANCH WELL

SPRING VALLEY SITE

FIGURE 22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