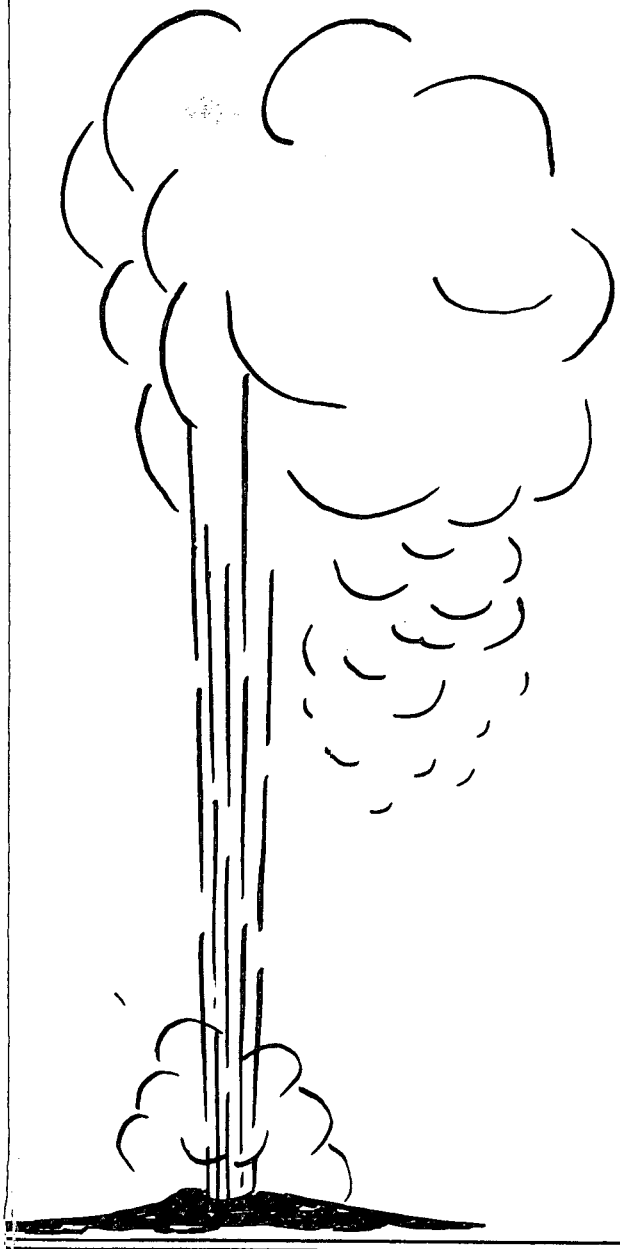
5/31/80 T.5

Lh. 1347

DOE/ET/28417-1

MASTER



GEOTHERMAL OBSERVATION WELLS MT. HOOD, OREGON

Final Report for October 4, 1977—July 9, 1979

By
W. F. Covert
H. J. Meyer

November 1979

Work Performed Under Contract No. ET-78-C-08-1565

Northwest Geothermal Corporation
Portland, Oregon

U. S. DEPARTMENT OF ENERGY
Geothermal Energy

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Final Report

For the Period

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123 N.W. Flanders Street
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ABSTRACT

Northwest Geothermal Corporation (NGC) as part of the geothermal resource assessment work in the Mt. Hood, Oregon vicinity, conducted exploration drilling operations which included the deepening of an existing hole, designated as Old Maid Flat #1, from 1,850 feet (564 m) to 4,002 (1,220 m) on the western approaches to Mt. Hood and the drilling of three new holes ranging from 940 feet (287 m) to 1,340 feet (409 m). The Clear Fork hole, located in Old Maid Flat, was drilled to 1,320 feet (402 m). The Zigzag hole was drilled to 940 feet (287 m) at the southwestern base of Mt. Hood in the Zigzag River valley. The remaining hole was drilled on the Timberline Lodge grounds which is on the south flank of Mt. Hood at an elevation of about 6,000 feet (1,829 m) above sea level.

The deepening project designated as Old Maid Flat #1 encountered a maximum bottom hole temperature of about 180°F (82°C) and is to this date the deepest exploratory hole in the Mt. Hood vicinity. No significant drilling problems were encountered. The Clear Fork and Zigzag River holes were completed without significant problems. The Timberline Lodge hole encountered severe drilling conditions, including unconsolidated formations. Two strings of tools were left in the hole from structural collapse of the hole. The hole was scheduled as a 2,000 foot (610 m) test. Drilling did not proceed beyond 1,350 feet (412 m) and due to junk it was unobstructed to a depth of 838 feet (255 m). Observation pipe was installed to 735 feet (224 m) due to further disintegration of the hole. The work was prematurely terminated due to weather conditions.

1. Introduction

This report describes the drilling in the Mt. Hood Oregon vicinity of four temperature observation holes.

Hole designations are as follows:

a. Old Maid Flat #1 (2S8E, 15cd)

b. Clear Fork (2S8E, 17cc)

c. Timberline (3S9E, 7aac)

d. Zigzag (3S8E, 14bc)

Northwest Geothermal Corporation provided drilling subcontractors and supervised the drilling under contract with the Department of Energy. Northwest Geothermal Corporation coordinated with the U.S. Forest Service and the U.S. Geological Survey for the site selection and environmental requirements.

2.2 Surface Equipment and Services

2.2.1 Drilling Rigs

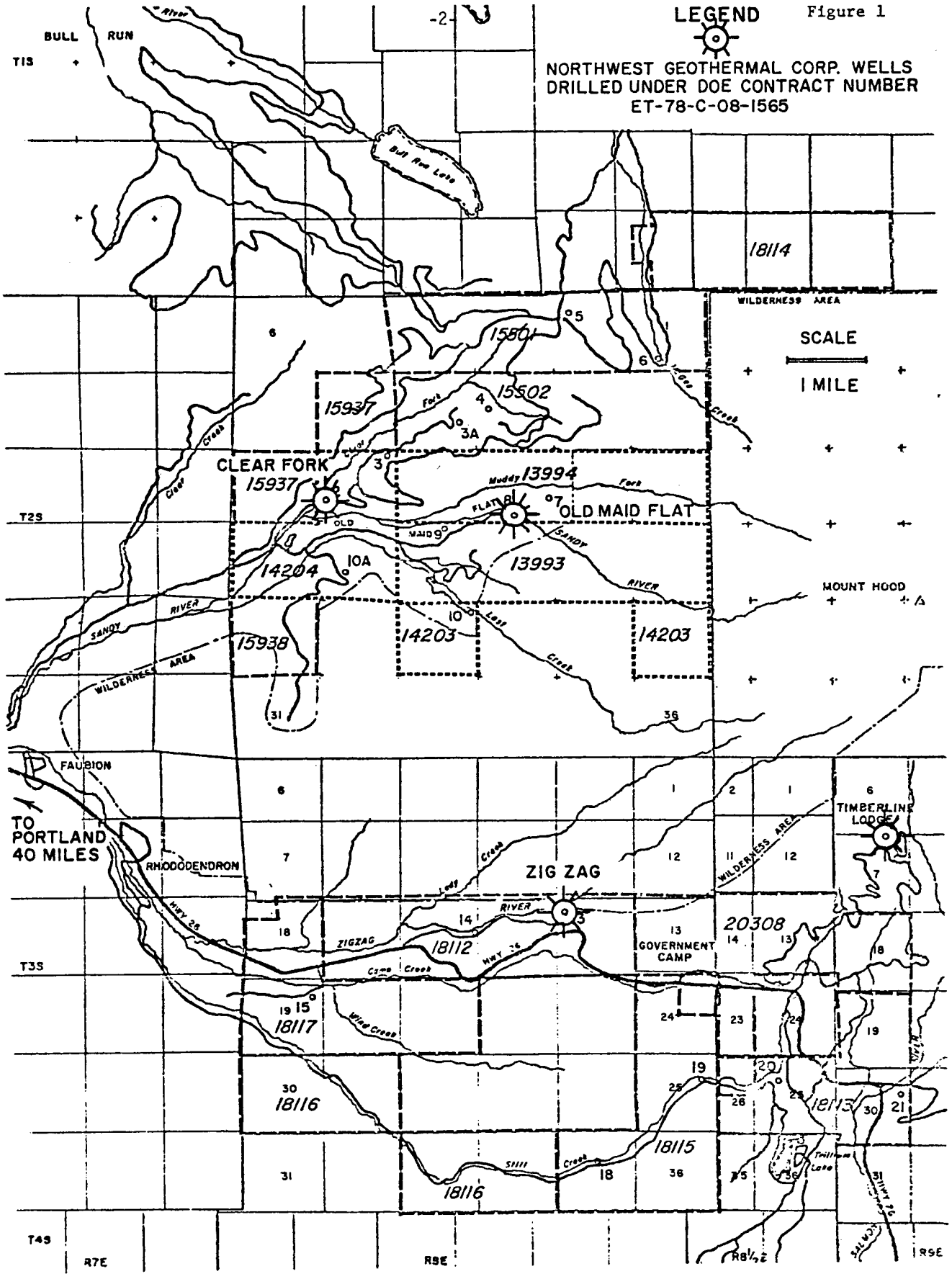
A.1 Old Maid Flat -- 1977

1. B.E. 24 L Cable Rig
2. Porta Drill 10 TG, with double drum drawworks (50,000# capacity), 38-foot mast (50,000# capacity), 450 CFM and a 1050 CFM air compressor.
3. Failing model 2500 CF, with double drum drawworks, bare drum pull of 15,000# (90,000# maximum capacity), 58 foot mast with 100,000# capacity, working hook load of 45,000# maximum lift 60,000#. Gasco 5-1/2" x 10" duplex pump with 320 HP engine.

A.2 Old Maid Flat - 1978

Used Taylor Drilling, Inc. rig #4. Drawworks unit was a model U-34 with 1" drilling line, 15" single Parkersburg Hydromatic brake, 225 HP Waukesha gas

Figure 1


LEGEND
NORTHWEST GEOTHERMAL CORP. WELLS DRILLED UNDER DOE CONTRACT NUMBER ET-78-C-08-1565
SCALE
1 MILE
BULL RUN
T1S
Bull Run Lake
18114
WILDERNESS AREA
15801
15937
15502
CLEAR FORK
15937
13994
OLD MAID FLAT
T2S
14204
10A
13993
MOUNT HOOD
14203
14203
15938
SANDY RIVER
WILDERNESS AREA
FAUBION
TO PORTLAND 40 MILES
RHODODENDRON
ZIG ZAG
TIMBERLINE LODGE
20308
GOVERNMENT CAMP
18112
T3S
18117
18116
18115
18116
T4S
R7E
R9E
R8½E
R9E

2.2 Surface Equipment and Services (cont.)
2.2.1 Drilling Rigs (cont.)

engine, a 97-foot Lee C. Moore mast (330,000# capacity) and a FXK Gardner Denver 7-1/4" x 14" pump with a 320 HP Cummings gas engine.

B. Clear Fork - 1978

Used a 1977 Cyclone Model TH 100 mounted on (4) four-axle crane with singe drawworks (58,000# capacity), 30-foot mast (100,000# capacity), 600 CFM at 250 psi Ingersoll Rand air compressor, 5-1/2" x 8" Gardner Denver mud pump.

C. Timberline - 1978

1. Used a 1973 Cyclone Rotary Model TH 60 Wellen casing hammer, single drawworks (15,000# capacity), 38-foot mast (40,000# capacity), 450 CFM at 250 psi air compressor.
2. Replaced above rig at 188 feet with 1977 Cyclone Model TH 100 mounted on (4) four axle crane with single drawworks (58,000# capacity), 38-foot mast (100,000# capacity), 600 CFM at 250 psi Ingersoll Rand air compressor, 5-1/2" x 8" Gardner Denver mud pump.

D. Zigzag - 1979

Used the 1977 Cyclone Model TH 100 mounted on (4) four-axle crane with single drawworks (58,000# capacity), 38-foot mast (100,000# capacity), 600 CFM at 250 psi Ingersoll Rand air compressor, 5-1/2" x 8" Gardner Denver mud pump.

3. Exploration Hole Drilling
3.1 Drilling Summary
3.1.1 Old Maid Flat #1

Northwest Geothermal Corporation prepared the site by minor cleanup of the abandoned parking lot at the Ramona Falls trailhead for the 1977 NGC drilling test. The hole was spudded on October 4, 1977 with a cable tool rig #1. A 12"

3. Exploration Hole Drilling (cont.)
3.1 Drilling Summary (cont.)
3.1.1 Old Maid Flat #1 (cont)

(30.5 cm) conductor pipe was drilled and hammered to 90 feet (27.4 m) with the rig. A rotary air rig #2 moved on the hole and drilled 10 inches (25.4 m) diameter to 150 feet (46 m). The hole was cased with 8-5/8" (22 cm) pipe and cemented with 80 sacks of cement (approximately 88 cu. ft. (2.5 cuM) on October 25, 1977. On October 27, 1977, a single gate B.O.P. with pipe rams was installed. Drilled with 7-7/8" (20 cm) insert bit to 385 feet (117 m) with rig #2. Moved on rig #3 (air and mud) November 8, 1977 and drilled to 885 feet (270 m) with air. Mixed mud because hydrostatic head of water exceeded capacity of air compressor and continued to 1,850 feet (564 m). Hole was discontinued due to rig breakdown. Two inch (5 cm) tubing was installed for observation. Temperature gradients were taken (See Addendum #1).

The well was reentered July 28, 1978 under contract with the Department of Energy.

New site preparation was required to accommodate a larger rig. The site was enlarged to 125 ft. x 175 ft. requiring the removal of several trees. The existing road was repaired and drained to eliminate damage due to rain and snow-melt runoff.

Rig #4 was moved and continued drilling a 7-7/8" (20 cm) hole using mud. Drilling was uneventful except for a twist off of a pin on a drill collar at 3,748 feet (1,143 m). The tools were retrieved with an overshot on the first try. Two inch (5 cm) tubing was run to 4,002 feet (1,220 m). The well was logged (See addendum #1). Initial cleanup of the site was completed at this time. See Figure #2 for completion data.

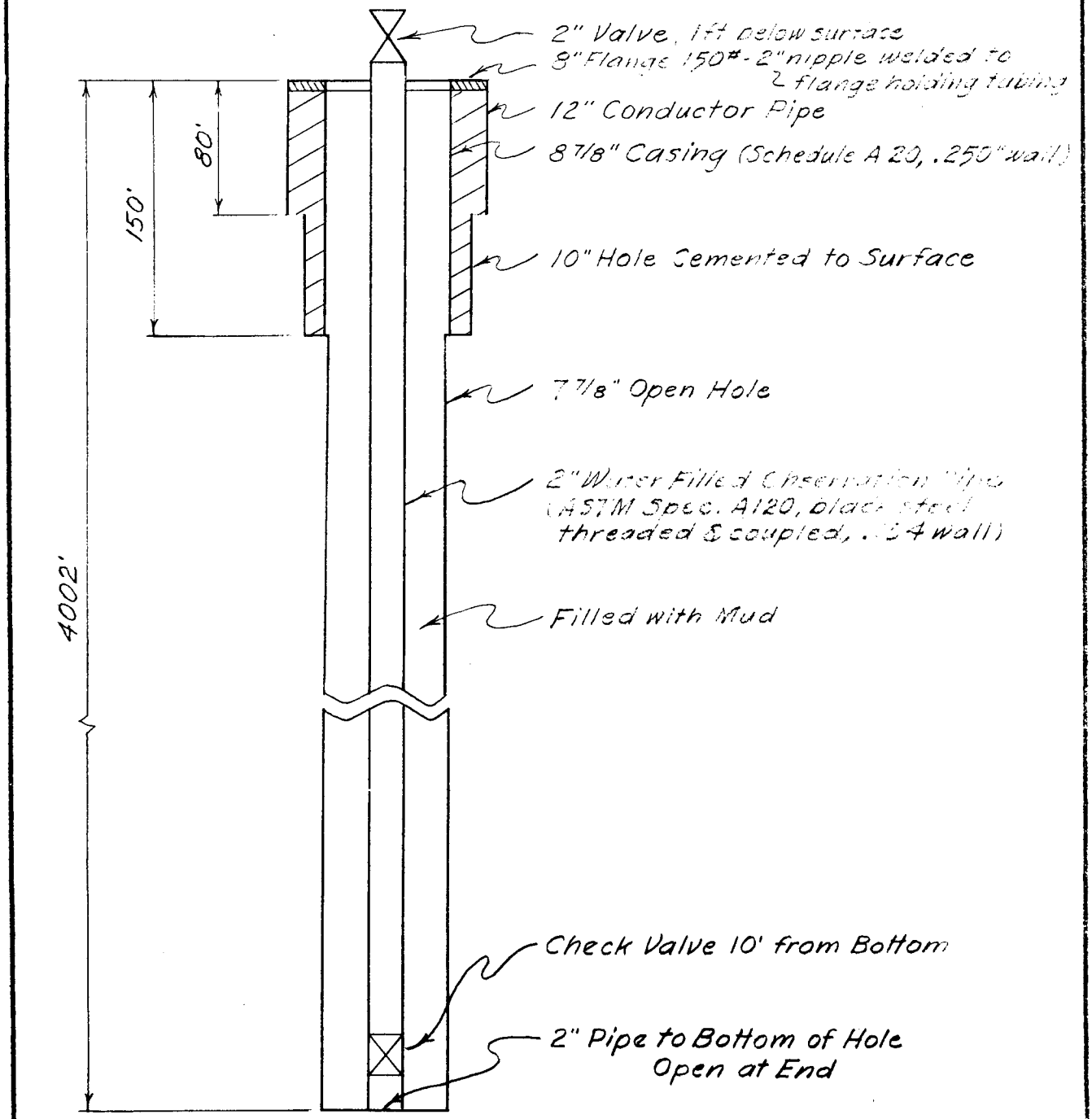


FIGURE 2

SYM.	DR.	APP.	REVISIONS	DATE	SYM.	DR.	APP.	REVISIONS	DATE
								Notes & 8" Flg	2-5-80
								Check V & 2" Pipe to Bottom	11-15-79

NORTHWEST GEOTHERMAL CORPORATION

DIAGRAM OF COMPLETED WELL
2S 8E 15CD OLD MAID FLAT

CH. DATE
APP. DATE
APP. DATE

DR. Fagan DATE 8-21-79
SCALE None
DWG. NO

3. Exploration Hole Drilling (cont.)
3.1 Drilling Summary (cont.)
3.1.2 Clear Fork Well

3.1.2 Clear Fork Well

The site was an area used as dump area for road construction material, including some asphaltic pavement. Access was from an existing paved road. No clearing of the site was required.

On November 29, 1978, the hole was spudded with a Cyclone TH 100 equipped for air or mud drilling. A 12-3/4" (32 cm) hole was mud -drilled to 200 feet (61 m).

Surface casing using 8-5/8" (22 cm) pipe was set and cemented to surface. The rig pump was used to circulate 100 sacks of cement (110 cu. ft. or 3.1 cu. M) plus 2% CaCl. Bottom and top cementing plugs were used. The hole was air drilled with a 7-7/8" (20 cm) insert bit to 360 feet (110 m). The hole was coverted to 6-1/4" (16 cm) with an insert bit and air drilled to 500 feet (152 m). On December 6, 1978, a single gate mechanical gate valve was installed for blow out control. The hole was continued to 900 feet (274 m). Conversion was made to mud drilling becuase of 50 gpm (3 lps) water production. Mud was contained in metal pits. Lost circulation was encountered at 1,140 feet (348 m) for a short time. Quick seal was used for lost circulation. Total depth of 1,320 feet (494 m) was reached on December 13, 1979. Two inch tubing (5 cm) was run to T.D. with a cap on bottom. Temperature tests were made at 500 feet (152 m) and after completion. See Addendum #2, well completion information. (See Figure #3 for completion data).

3.1.3 Timberline Well

This site was located just below the Timberline Lodge maintenance shop on Mt. Hood. The site was on the edge of the parking lot so no preparation was necessary. On July 20, 1978, drilling was started with a Cyclone TH 60 using a 12"

6096 NS

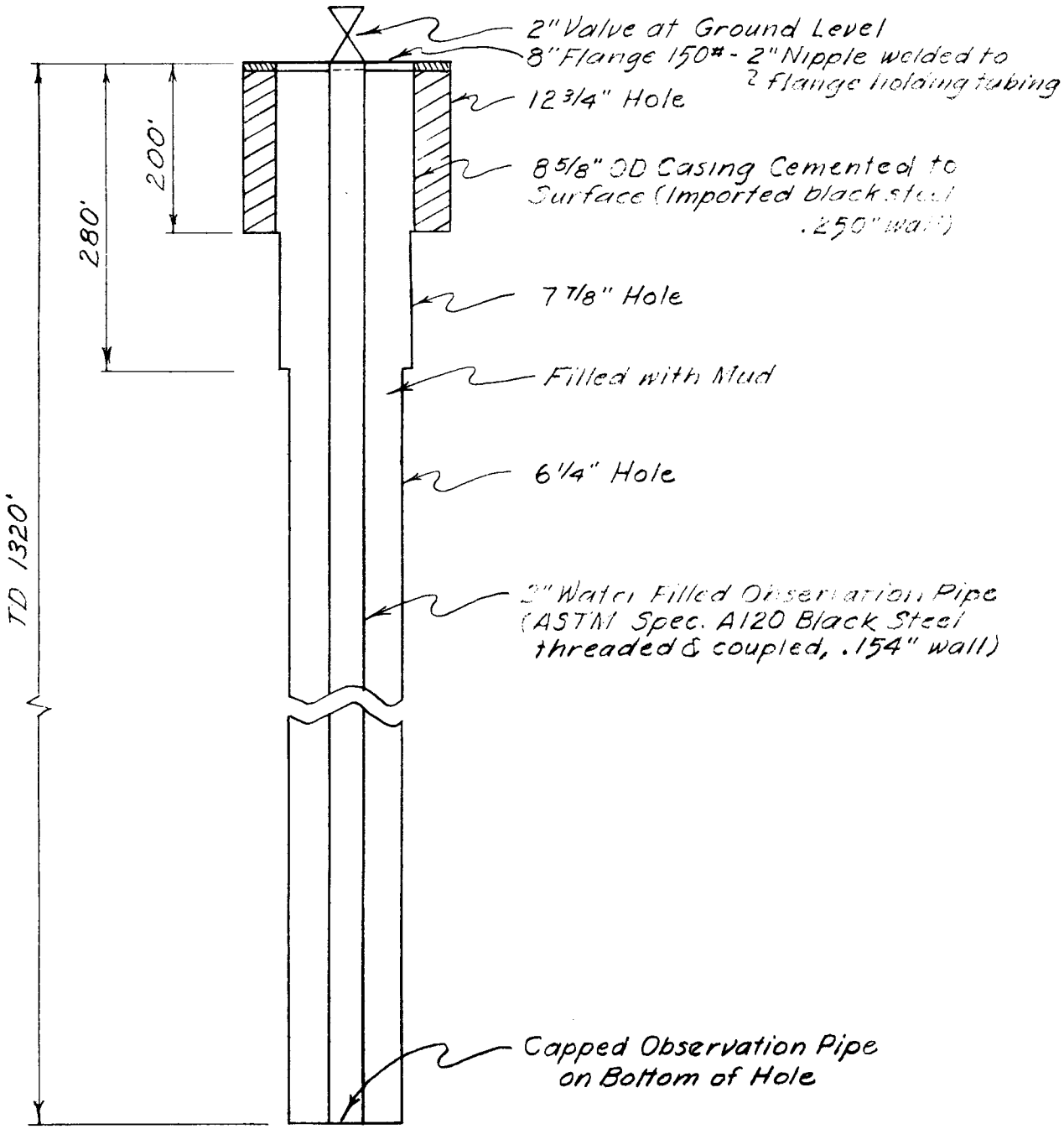


FIGURE 3

SYM.	DR.	APP.	REVISIONS	DATE	SYM.	DR.	APP.	REVISIONS	DATE
								Notes + 8" Flg	2-5-80
								Cap. Obs. Pipe	11-15-79

CH. DATE	NORTHWEST GEOTHERMAL CORPORATION GEOTHERMAL TEST WELL 2S 8E 17CC CLEAR FORK	DR. Fagan DATE 8-21-79
APP. DATE		SCALE None
APP. DATE		DWG. NO

3. Exploration Hole Drilling (cont.)
3.1 Drilling Summary (cont.)
3.1.3 Timberline Well

(30.5 cm) rotary air hammer and casing hammer. Twelve inch (30.5 cm) conductor pipe was driven to a depth of 90 feet (27 m) where one of the welds broke on the conductor pipe. Drilling continued with the 12 inch (30.5 cm) hammer to a depth of 188 feet (57 m) at which point the hammer was found to be cracked. The TH 60 was released at this point and a TH 100 was located on site. Drilling then continued with a 10 inch (25 cm) rotary air hammer to a depth of 400 feet (122 m). Temperature measurements were attempted at this time inside the drill pipe without success. The probe would not clear the tool joints because of weight and shape. Four hundred feet (122 m) of 8-5/8" casing (22 cm) was set and cemented with 120 sacks of cement (132 cu. ft. or 3.7 cu. M) and 3% CaC1. The annular space between casing and hole was then cemented to surface using two rubber plugs and the rig pump. One hundred sacks (110 cu. ft. or 3.1 cu M) plus 3% CaC1 was used.

The B.O.P. was set and tested at 300 psi for 20 minutes, witnessed by the U.S.G.S. The plug was drilled out using air and 7-7/8" (20 cm) insert bit. Circulation was lost for about six hours at 470 feet (143 m). At 490 feet (149 m) the hole was tripped for bit check. The hole had filled in to 450 feet (137 m). The hole was cleaned and the tools removed. The hole was cemented by pouring at the top of the casing with 150 sacks of cement (165 cu. ft. or 4.7 cu M) and 300# of CaC1 was used. Cement was drilled out and the top was found at 300 feet (91 m) and the bottom at 465 feet (142 m). The hole was drilled to 790 feet (241 m) and caved back to 771 feet (235 m). Water (43°F or 6°C) was produced at a rate of 100 gpm (6.3 lps). The open hole was cemented from the surface by pouring 100 sacks (110 cu. ft. or 3.1 cu. M) with 3% CaC1. The cement was washed out by water migrating through the hole. Hole was recemented with 125 sacks of cement (137.5 cu. ft. or 3.9 cu. M) and 3% CaC1 with no success. The hole was recemented

3. Exploration Hole Drilling (cont.)
3.1 Drilling Summary (cont.)
3.1.3 Timberline Well (cont.)

with 100 sacks (110 cu. ft. or 3.1 cu. M), 3% CaCl, 100# of Flocele and 40 cu. ft. (1.1 cu. M) of permalite, after the hole was conditioned with 800 gallons (3,024 l) of heavily mixed mud with gel and 40 cu. ft. (1.1 cu. M) of sawdust. Hole was cleaned to 755 feet (230 m) with the production of 10 to 15 gpm (.6 to .9 lps). The upper water zones were fairly well shut off. At 770 feet (235 m) the cement was found washed out and large volumes of water were produced. The drill pipe became stuck at 750 feet (228.5 m) while squeezing water-bearing formation at 770 feet (235 m). Cleared pipe and circulated with 1,000 gallons (3,780 l) of water with no back pressure. Connection was made to an air compressor pumping 1,200 cfm (34 cmm) and 60# back pressure which was normal pressure.

Hydraulic jars were used to back off the drill pipe at 617.5 feet (188 m). A 6-5/8" (17 cm) washover pipe was assembled to drill over the fish with no success. The washover pipe twisted off near the top of the old fish, leaving 132 ft. (40 m) around it. A T.V. camera was run in the hole and it showed the end of the washover pipe spread and badly twisted. Recovery was deemed a worthless venture.

A cement plug was pumped on top of the fish using 80 sacks (88 cu. ft. or 2.5 cu.M) and 3% CaCl. Cement cured for five days waiting on new tools. When the hole was cleaned out the top of the cement was found at 397 feet (121 m). The bit drilled off the cement plug at 477 feet (145 m). The hole was cleaned to 570 feet (174 m) and cemented with 100 sacks (110 cu. ft. or 3.1 cu. M) and 3% CaCl. Drilled to 770 feet (235 m) into hard andesite and making 40 to 50 gpm (2.5 to 3.2 lps). Cement was spotted at bottom using 30 sacks (33 cu. ft. or 9 cu. M) and 80# CaCl plus 8 cu. ft. (.2 cu. M) of Permalite. Redrilled to 770 feet

3. Exploration Hole Drilling (cont.)
3.1 Drilling Summary (cont.)
3.1.3 Timberline Well (cont.)

(235 m), still making 20 gpm (1.3 lps) of water. Recemented with 20 sacks (22 cu. ft. or .6 cu. M) and 3% CaCl plus 20 cu. ft. (.56 cu. M) of Zonelite. Water was shut off. Drilling continued to 880 feet (268 m). Water was encountered between 800-820 feet (244-250 m). Forty sacks of cement (44 cu. ft. or 1.2 cu. M) and 3% CaCl) plus 40 cu. ft. (1.1 cu. M) of Zonelite. The cement was drilled out to 850 feet (259 m). Cement was soft. Recemented the hole with 60 sacks (66 cu. ft. or 1.9 cu. M) and 3% CaCl plus 60 cu. ft. (1.7 cu. M) of Zonelite. The hole was drilled to 940 feet (286 m) and cemented with 16 sacks of cement (17.5 cu. ft. or .5 cu. M) and 3% CaCl plus 16 cu. ft. (.45 cu. M) of Zonelite. The hole was drilled to 960 feet (293 m) and was then cemented with 30 sacks (33 cu. ft. or .9 cu. M), 3% CaCl and 30 cu. ft. (.85 cu. M) of Zonelite. Drilling was continued to 1,140 feet (347 m) and a trip was made to check bit and run 3-1/2 LF (8.9 cm) drill string. Caving problems and water from 900 feet (274 m) caused another cement job with 16 sacks of cement (17.6 cu. ft. or .5 cu. M) with 3% CaCl and 16 Cu. ft. (.45 cu. M) of vermiculite. A temperature was taken at 984 feet (300 m) indicating approximately 47 F (8.3 C).

Drilling was converted to mud at approximately 1,000 feet (305 m). Drilling was continued to 1,340 feet (408 m) approximately. Large volumes of cuttings were circulated to surface. The rig shut down to clean pits and mix new mud. The new mud was circulated but the tools were stuck in the hole. Full circulation was established with no results. Hydraulic jars were used in an attempt to free the pipe. Fishing tools and expertise was obtained from Midway Fishing Tool Company and G. O. Wireline Services. G. O. stretch point tools would not operate properly. The string was unthreaded at 836 feet (255 m) using hydraulic jars. The pipe was tripped out and the hydraulic jars were installed and run to the fish and recon-

3. Exploration Hole Drilling (cont.)
3.1 Drilling Summary (cont.)
3.1.3 Timberline Well (cont.)

nected. The jars fired twice and failed. G. O. ran a charge to the connection below the jars and freed the connection again and removed it. New jars were installed and run in to reestablish connection with the fish. Reconnection was made and the drill pipe twisted off 4 feet (1.2 m) below the connection. The connection and twist-off was not felt in the process. Due to the condition of the drill pipe at the separation it was felt that continued fishing was not practical.

A cement plug of 25 sacks of cement (27.5 cu. ft. or .8 cu. M) with 3% CaCl was spotted over the fish. The plug was left to cure for four days. The plug was soft and no kick-off occurred. The plug was repeated with the same results. The plug was again placed using 28 sacks of calcium aluminate and 7 sacks of posalin fly ash. The plug was cleaned to 800 feet (244 m). The redrill would not kick off because the plug didn't harden as expected. A 6-14" (16 cm) bit was run in a final attempt to kick off without success. Recementing was attempted but the drill pipe plugged and had to be pulled and washed. Due to very bad weather conditions the drilling was suspended. Two inch (5 cm) tubing was run to 735 feet (224 m).

The 2,000-foot (610 m) objective was not achieved. However, the hole could be reentered and completed with proper equipment. Lessons were learned from this project. Drilling volcanic cones is very difficult and in this case it was compounded by interbedded unconsolidated debris and lava flows. Due to the very loose unconsolidated formations and the migrating water, cementing was difficult. Cementing methods were devised which seem to work under these drilling conditions. The use of Permelite aggregate allowed us to have a slurry containing a lost circulation material plus the aggregate screened out in the hole and provided a

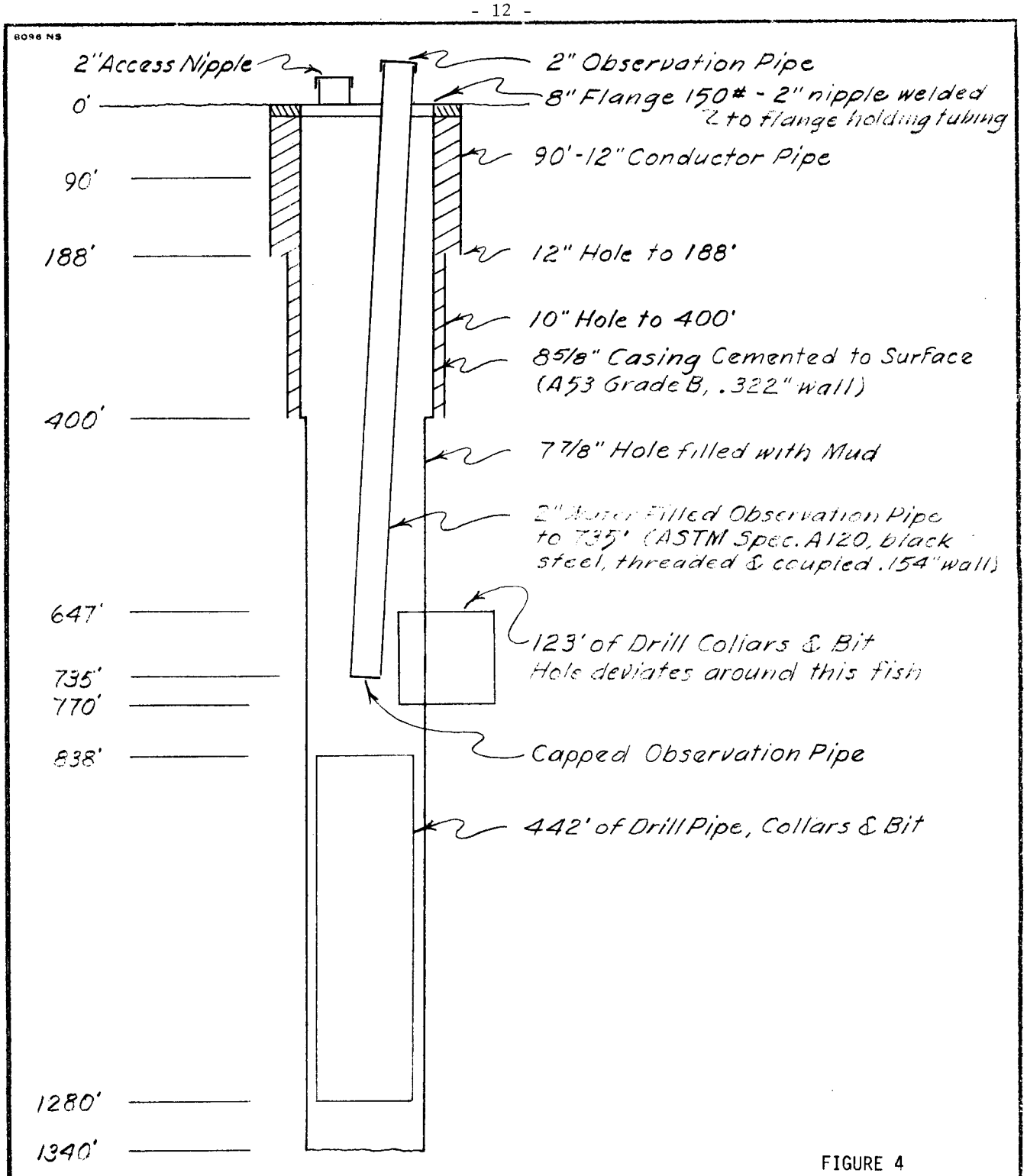


FIGURE 4

SYM.	DR.	APP.	REVISIONS	DATE	SYM.	DR.	APP.	REVISIONS	DATE
								Notes & 8" Flg	2-5-80
								Cap. Obs. Pipe	11-15-79

CH. DATE	NORTHWEST GEOTHERMAL CORPORATION	DR. Fagan DATE 8-21-79
APP. DATE	DIAGRAM OF COMPLETED WELL	SCALE None
APP. DATE	3S 9E 7AAC TIMBERLINE LODGE	DWG. NO.

3. Exploration Hole Drilling (cont.)
3.1 Drilling Summary (cont.)
3.1.3 Timberline Well (cont.)
3.1.4 Zigzag River Well

soft plug which allowed the bit to stay in the hole.

See Figure #4 for completion data.

See Addendum #3 for tests.

3.1.4 Zigzag River Well

The site was at the end of the old Hwy 26 past the Kiwanis campgrounds. No clearing was required for the portable drilling rig. Access was by existing roads. On June 6, 1979, drilling was started with a Cyclone TH 100 using an air hammer. A 7-1/4" (16 cm) hammer bit was used to 200 feet (61 m) then reamed out with 10" (25 cm) opener. The hole was cleaned with a 9-7/8" (25 cm) roller cone bit. Had to cement the 25-to 40-foot (7.6 to 12 m) interval due to fracture caving. Ran and cemented 200 feet of 8-5/8" (22 cm) casing.

On June 21, 1979, switched to mud at 500 feet (152 m). Had small cavities from 575 feet to 630 feet (175 m - 192 m). At 750 to 760 feet (228 - 232 m) had a water loss but not sufficient to cause problems. We used an 8" (20 cm) gate valve with 2" (5 cm) kill lines as a blow out preventor. This was installed June 20, 1979, at 470 feet (143 m). The drilling of this hole was very slow and at 940 feet (287 m) the pipe refused to turn when on bottom. They tripped out and found that all three roller cones were gone from bit.

At this time (July 9, 1979) it was decided not to go any deeper with this well. On July 10, 1979, 2" (5 cm) tubing was installed and welded to flange. (See Addendum #4 for logs and Figure 5 for completion data).

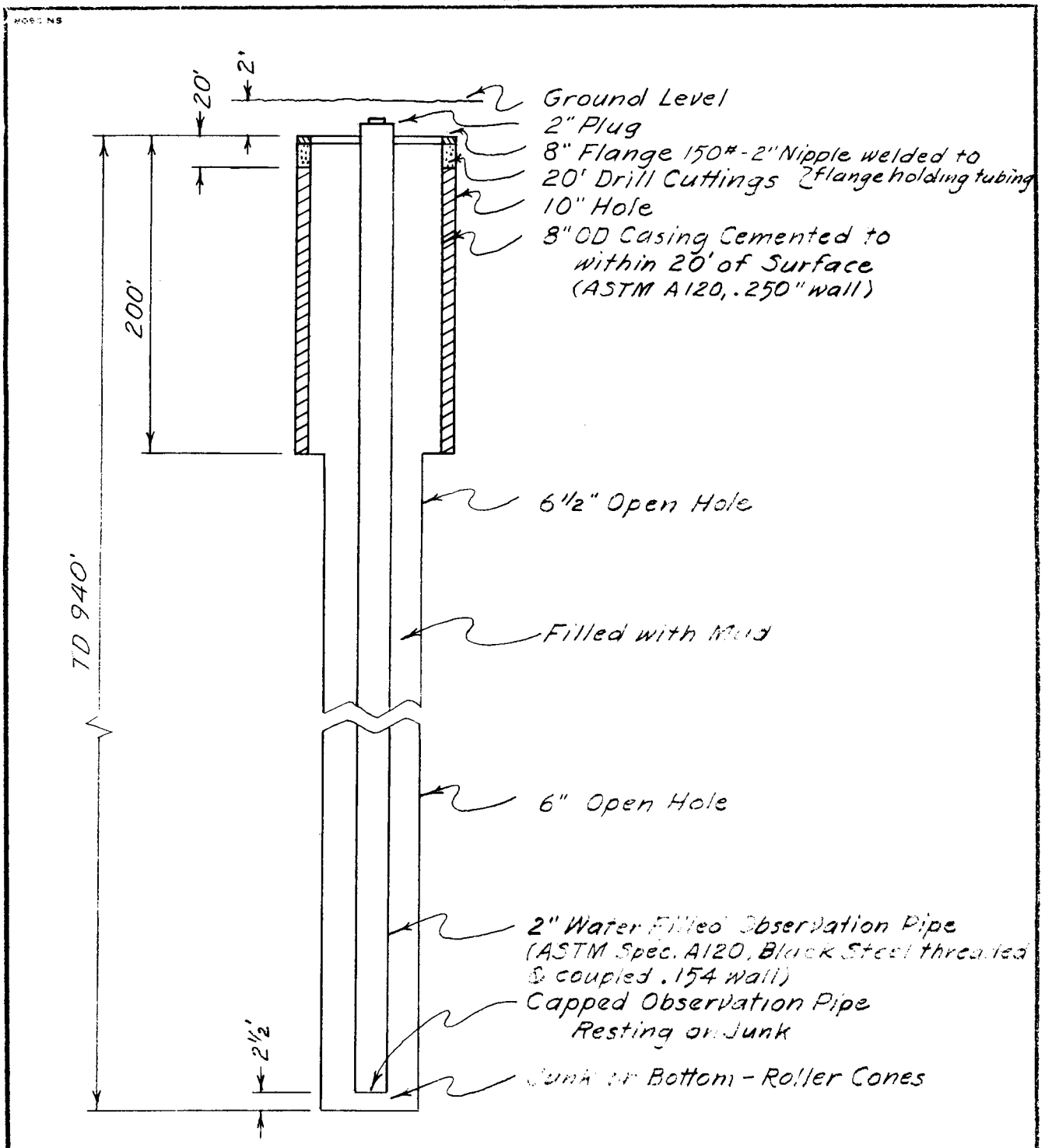


FIGURE 5

SYM.	DR	APP.	REVISIONS	DATE	SYM.	DR.	APP.	REVISIONS	DATE
								Notes & 8" Flg	2-5-80
								Cap. Obs. Pipe	11-15-79

CH. DATE	NORTHWEST GEOTHERMAL CORPORATION	DR. Fagan DATE 8-21-79
APP. DATE	GEOTHERMAL TEST WELL	SCALE None
APP. DATE	3S 8E 14BC ZIGZAG	DWG. NO.

4. Downhole Equipment and Services
4.2 Drilling Fluid Summary
4.2.1 Old Maid Flat

Duplicate drill cutting samples were obtained approximately every 10 feet (3 m) by our geologists. One sample was sent to the State of Oregon, and Northwest Geothermal Corporation retained one sample.

The wells were drilled with fresh water base gel mud. Mud, with a weight of 9.6 lb/gal was left in each hole.

4.2.2 Clear Fork Well

a. Drilled with fresh water base gel mud to 200 feet (61 m).

b. Drilled with air and foam to 900 feet (274 m).

c. Drilled with fresh water base gel mud from 900 feet (274 m) to 1,320 feet (402 m). Heavy mud left in hole around observation pipe.

4.2.3 Timberline Well

a. Drilled with air and foam to 1,140 feet (348 m).

b. Drilled with fresh water base gel mud to 1,340 feet (409 m). Lost hole to 840 feet (256 m). Set observation pipe in heavy mud to 735 feet (244 m).

4.2.4 Zigzag River Well

a. Drilled with air and foam to 495 feet (151 m).

b. Drilled from 495 feet (151 m) to 940 feet (274 m) with fresh water based gel mud. Set observation pipe at 940 feet (274 m) with heavy mud.

4.3 Logging Program

Commerical logs were run on the Old Maid Flat well by Welex. They consisted of a

4. Downhole Equipment and Services (cont.)
4.3 Logging Program (cont.)

density log, temperature log, acoustic log, dual induction log, fracture finder log and drift log (deviation) from the base of the surface casing (150 ft.) to total depth (4002 ft.). They are on file with the Oregon Department of Geology and Mineral Industries and with the U.S.G.S. Conservation Division, Santa Rosa, California. On November 16, 1978, the U.S.G.S. out of Menlo Park, California ran a temperature log. A copy is also on file with the State of Oregon. Temperature logs have been run on the other wells and are on file with the Oregon Department of Geology and Mineral Industries.

4.4 Drill Bit Summary
4.4.1 Old Maid Flat - From 1,850 feet (564 m) to 4,002 feet (1,220 m).

a. Drilled to 2,085 ft. (635 m) with 7-7/8" (20 cm) milled tooth bit. 27-1/4 hours

b. Drilled to 3,155 feet (962 m) with 7-7/8" (20 cm) journal bearing button bit. 132-1/2 hours

c. Drilled to 4,002 feet (1,220 m) with 7-7/8" (20 cm) journal bearing button bit. 146 hours

4.4.2 Clear Fork Well

a. Drilled to 200 feet (61 m) with 12-1/4" (31 cm). mill tooth bit. 16 hours

b. Drilled from 200 feet (61 m) to 280 feet (85 m) with 7-7/8" (20 cm) journal bearing button bit. 4 hours

c. Drilled from 280 feet (85 m) to 1,320 feet (402 m) with a 6-1/4" (16 cm) journal bearing button bit. 55-1/4 hours

4.4.3 Timberline Well

a. 12-5/8" (32 cm) casing was driven behind a 12" (30 cm) air hammer bit

4. Downhole Equipment and Services (cont.)
4.4 Drill Bit Summary (cont.)
4.4.3 Timberline Well (cont.)

to 90 feet (27 m).

b. Drilled 12" (30 cm) with air hammer to 188 feet (57 m). 66 hours

c. Drilled with 10" (25 cm) air hammer from 188 feet (57 m) to 400 feet (122 m). 13-3/4 hours

d. Drilled from 400 feet (122 m) to 770 feet (235 m) with 7-7/8" (20 cm) journal bearing button bit. Lost in hole, no recovery. 28 hours

e. Drilled from approximately 477 ft. (145 m) to 1,340 feet (409 m). Lost bit at 1,280 feet (390 m). No recovery. 63-1/2 hours

4.4.4 Zigzag River Well

a. Pilot drilled from surface to 200 feet (61 m) with 6-1/4" (16 cm) air hammer bit. Used bit. 9 hours

b. Reamed from surface to 200 feet (61 m) with 10" (25 cm) air hammer bit. Bit still good. 20 hours

c. Drilled from 200 feet (61 m) to 370 feet (113 m) with 6-1/2" air hammer. Bit still good. 13 hours

d. Drilled from 370 feet (113 m) with 6-1/4" (16 cm) journal bearing button bit to 940 feet (287 m). Lost cones. Ran 68 hours

5. Lithology
5.1 General Statement

All rocks exposed or drilled in the Mt. Hood area to date are of igneous origin. The intrusive rock ranges from basalt to quartz diorite. The extrusive rock ranges from basalt to dacite with andesite being the predominant rock type.

Most drill sites in the Mt. Hood area have a veneer of Mt. Hood block and ash flow material (mudflow). Once this layer of unconsolidated rock is penetrated, lava flows or consolidated mudflows are encountered. In the highly fractured areas

5. Lithology (cont.)
5.1 General Statement (cont.)
5.2 Detailed Lithology

of these rocks partial or complete loss of circulation of drilling fluids is not uncommon.

On the cone of Mt. Hood itself the unconsolidated block and ash flows are interbedded with lava flows. The thickness of the individual units is quite variable.

The block of ash flows are excellent aquifers. They are also unstable and subject to caving or ravelling when drilled.

5.2 Detailed Lithology

a. Mt. Hood clastics (mudflows). Unconsolidated block and ash flow andesites of Mt. Hood. The size of the constituents ranges from sand to boulders three feet (1 m) in diameter. Late Pleistocene to Recent in age. Found in most stream valleys around the flanks of Mt. Hood as well as on the mountain itself.

b. Mt. Hood Lavas: Olivine, hornblende or pyroxene andesite lava flows of Mt. Hood. Late Pleistocene to recent in age.

c. Still Creek-Laurel Hill Instrusions: Quartz diorite of Late Miocene to Early Pliocene age. Moderately altered.

d. Rhododendron Formation: Consolidated andesitic block and ash flows (mudflows) interbedded with lava flows of andesites or basaltic-adesite composition. Block and ash flows range from tuffs to breccias. Rare black shale beds. Formation is strongly altered in the Old Maid Flat area. Late Miocene to Early Pliocene in age.

e. Gabbro Intrusive: Gabbro sill? found only in the Old Maid Flat drill hole at a depth of 3,520 feet (1,073 m).

5. Lithology (cont.)
5.2 Detailed Lithology (cont.)

f. Columbia River Basalt Group: Tholeiitic flood basalts of the Yakima Basalt Subgroup. Found in the Old Maid Flat drill hole interbedded with Miocene volcanics from a depth of 2,028 feet (618 m) to 3,850 feet (1,174 m). Very little alteration. Miocene in age.

g. Miocene Volcanics: Volcanic rocks contemporaneous with the Columbia River Basalt Group. Generally a pale green crystal tuff of andesitic composition. Found in both the Old Maid Flat and the Clear Fork drill holes. Much thinner in the Clear Fork drill hole. Product of a local vent.

h. Unnamed Rock Below the Columbia River Basalt: Pale green crystal tuff encountered in the Old Maid Flat drill hole below the Columbia River Basalt from 3,850 feet (1,174 m) to 4,002 feet (1,220 m). May be related to the John Day Formation of Eastern Oregon of Late Oligocene to Early Miocene age.

6. General Comments

6.1 For a successful drilling program in the Mt. Hood area, the merits of each site such as: size, access, availability of water, mud pits, fluid and cuttings disposal and thickness of unconsolidated mudflow debris should be considered along with the geological reasons for drilling at that site.

6.2 It was found that drilling the unconsolidated mudflow debris with mud was the fastest and safest way to set surface casing.

6.3 The flexibility to use either air or mud for the final drilling should be retained.

6. General Comments (cont.)

6.4 In certain types of holes there is considerable merit to drilling a minimum size hole. This seems to reduce the stability problem in the unconsolidated mud-flows.

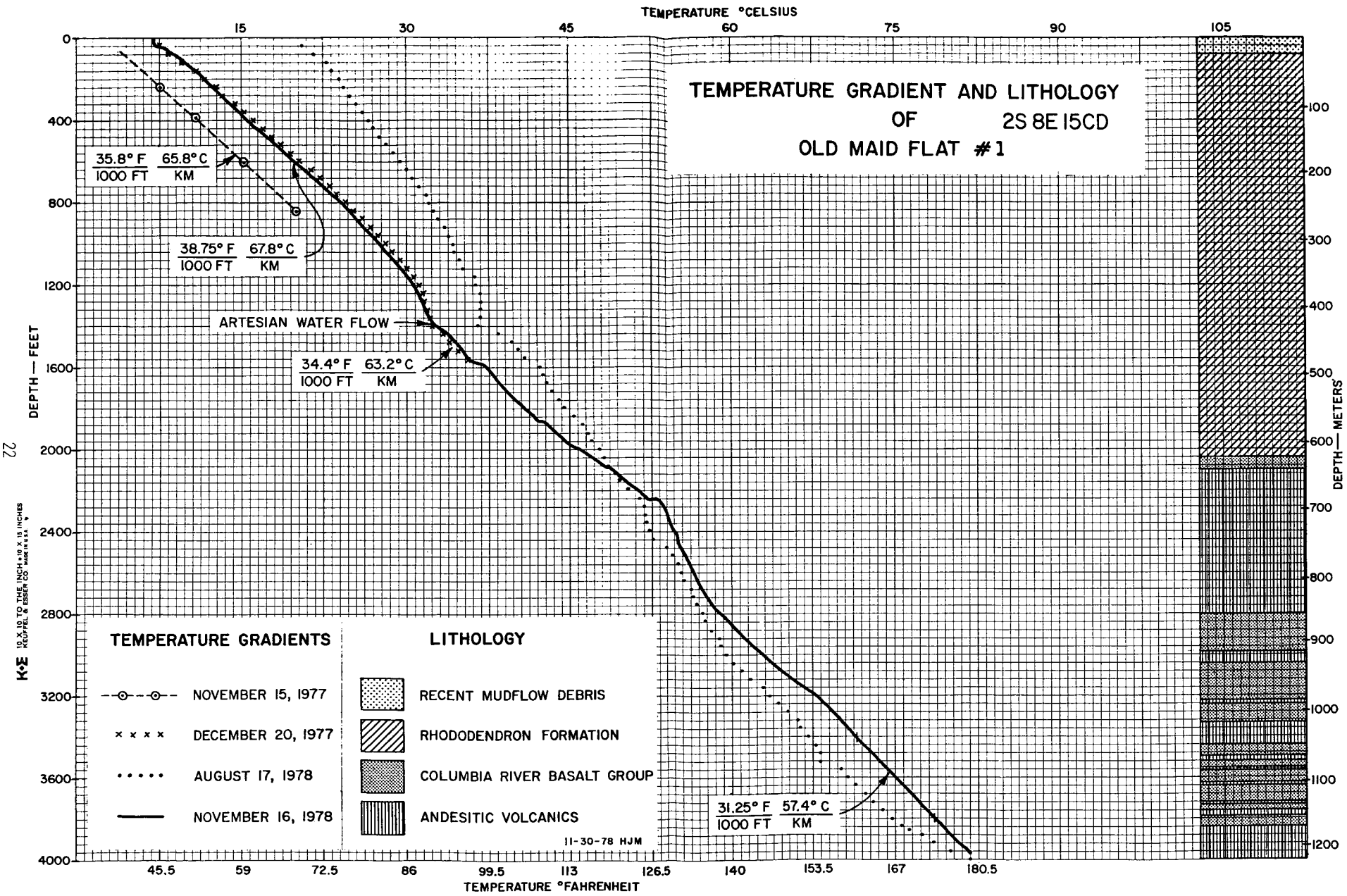
6.5 Conductor pipe can be set rapidly through very loose overburden with a casing hammer.

6.6 For drill holes over 2,000 feet (610 m) or for 24 hour rig operation, surface casing should be set by a smaller rig. This is a judgement factor based on surface geology.

ACKNOWLEDGEMENTS

We would like to thank G.F. Rogers for reviewing and editing this report. This project also benefitted from the assistance and geological expertise of J.W. Hook.

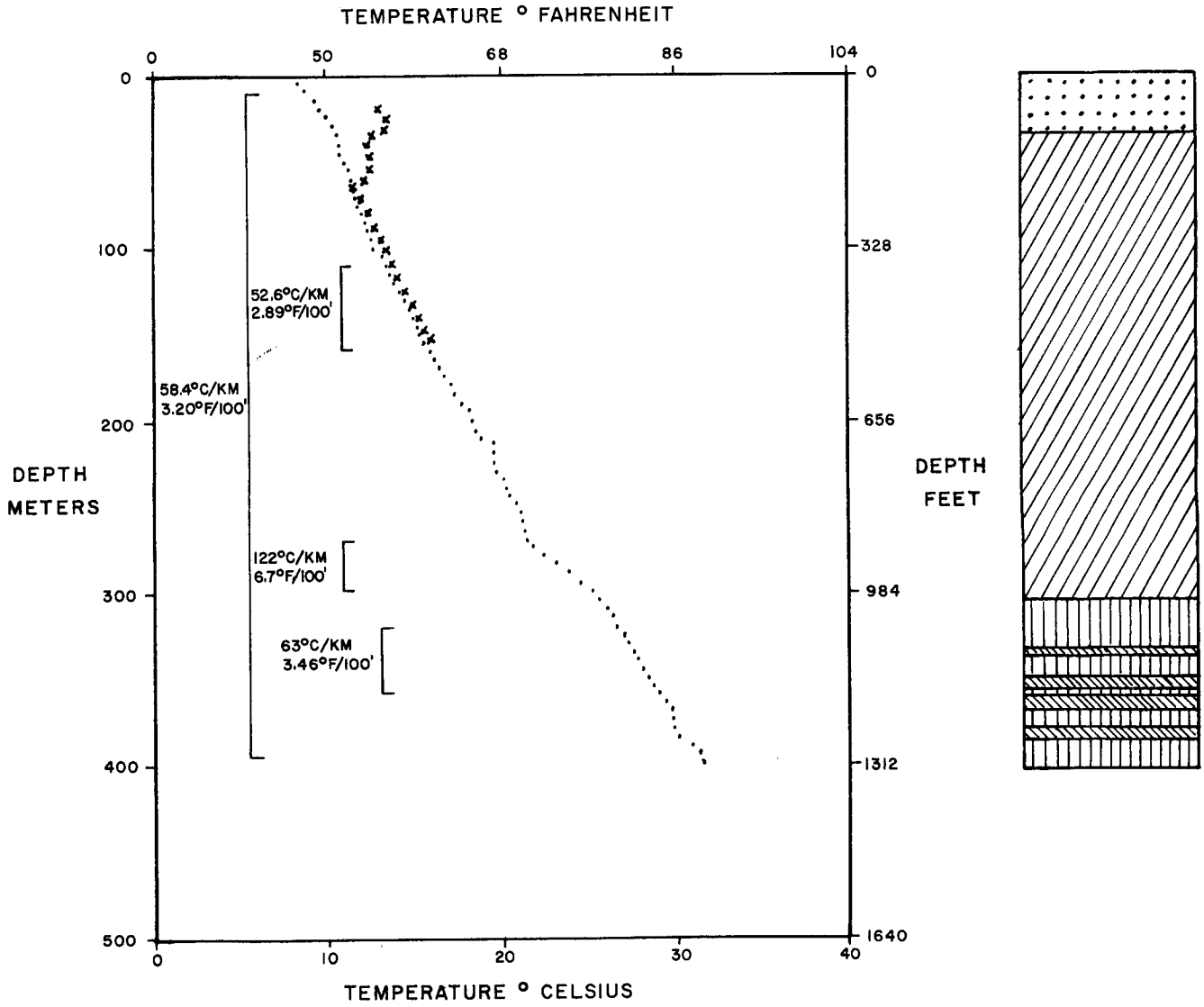
ADDENDUM #1


TEMPERATURE GRADIENT AND LITHOLOGY
OF 2S 8E 15CD
OLD MAID FLAT #1
TEMPERATURE °CELSIUS
15
30
45
60
75
90
105
DEPTH — FEET
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
DEPTH — METERS
100
200
300
400
500
600
700
800
900
1000
1100
1200
35.8° F / 1000 FT
65.8° C / KM
38.75° F / 1000 FT
67.8° C / KM
ARTESIAN WATER FLOW
34.4° F / 1000 FT
63.2° C / KM
31.25° F / 1000 FT
57.4° C / KM
TEMPERATURE GRADIENTS
NOVEMBER 15, 1977
DECEMBER 20, 1977
AUGUST 17, 1978
NOVEMBER 16, 1978
LITHOLOGY
RECENT MUDFLOW DEBRIS
RHODODENDRON FORMATION
COLUMBIA RIVER BASALT GROUP
ANDESITIC VOLCANICS
11-30-78 HJM
45.5
59
72.5
86
99.5
113
126.5
140
153.5
167
180.5
TEMPERATURE °FAHRENHEIT
K+E 10 X 10 TO THE INCH • 10 X 15 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

ADDENDUM #2

NORTHWEST GEOTHERMAL CORP.

TEMPERATURE GRADIENT AND LITHOLOGY OF 2S 8E 17CC CLEAR FORK



TEMPERATURE GRADIENTS

x DEC 5 1978

• DEC 21 1978

LITHOLOGY

RECENT MUDFLOW DEBRIS

RHODODENDRON FORMATION

COLUMBIA RIVER BASALT GROUP

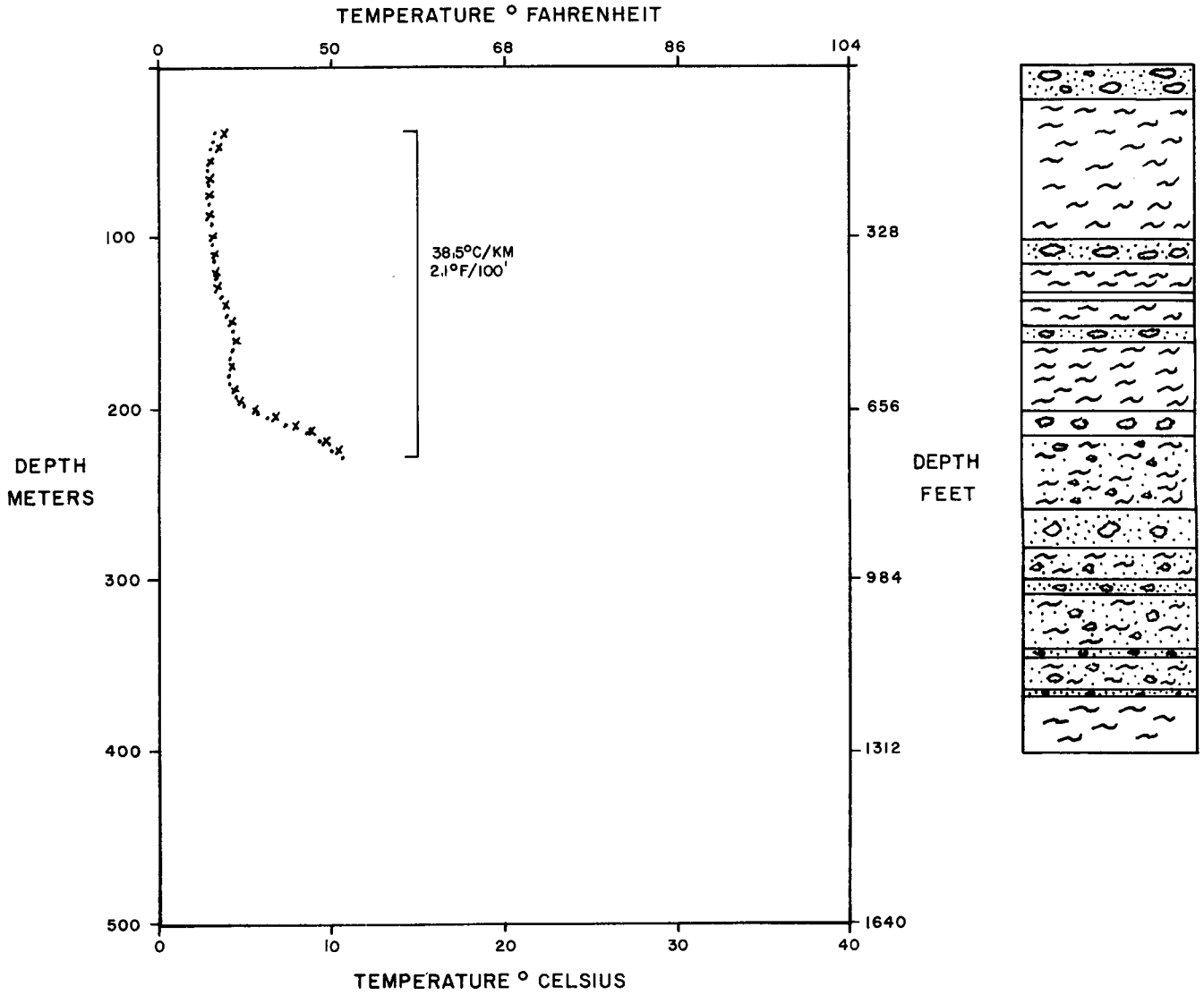
ANDESITIC VOLCANIC ROCK

HJM JAN 1979

ADDENDUM #3

NORTHWEST GEOTHERMAL CORP.

TEMPERATURE GRADIENT AND LITHOLOGY OF TIMBERLINE #3 3S 9E 7AAC



TEMPERATURE GRADIENTS

x DEC 13 1978

• DEC 28 1978

LITHOLOGY *

ANDESITE AND DACITE MUDFLOW BRECCIA

ANDESITE LAVA FLOWS

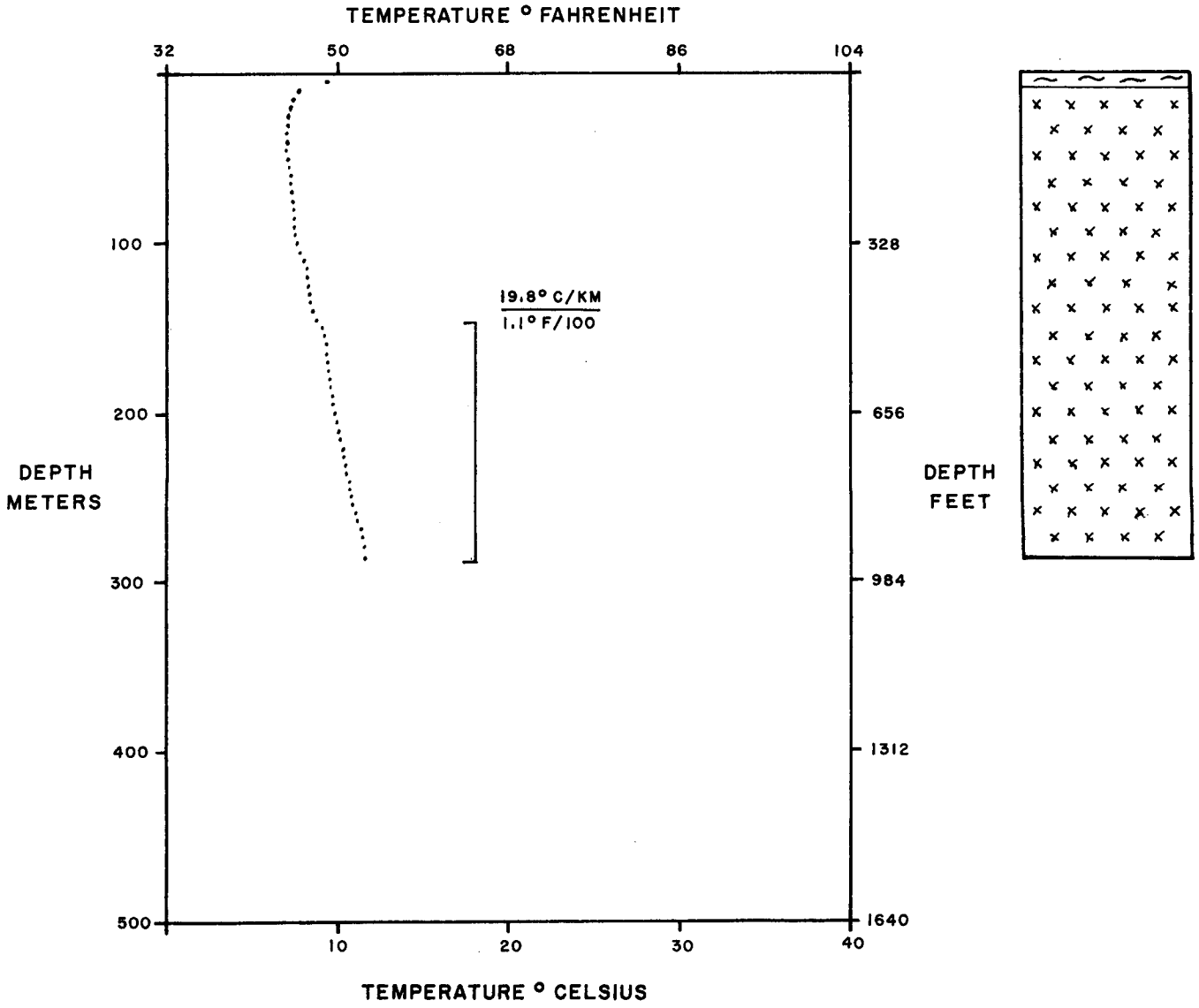
* AS DESCRIBED BY C. WHITE

HJM JAN 1979

ADDENDUM #4

NORTHWEST GEOTHERMAL CORP.

TEMPERATURE GRADIENT AND LITHOLOGY OF ZIG ZAG WELL 3S 8E 14 bc



TEMPERATURE GRADIENTS

SEPT. 25, 1979

LITHOLOGY

MT. HOOD ANDESITE

STILL CREEK - LAUREL HILL INTRUSION-QUARTZ DIORITE

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