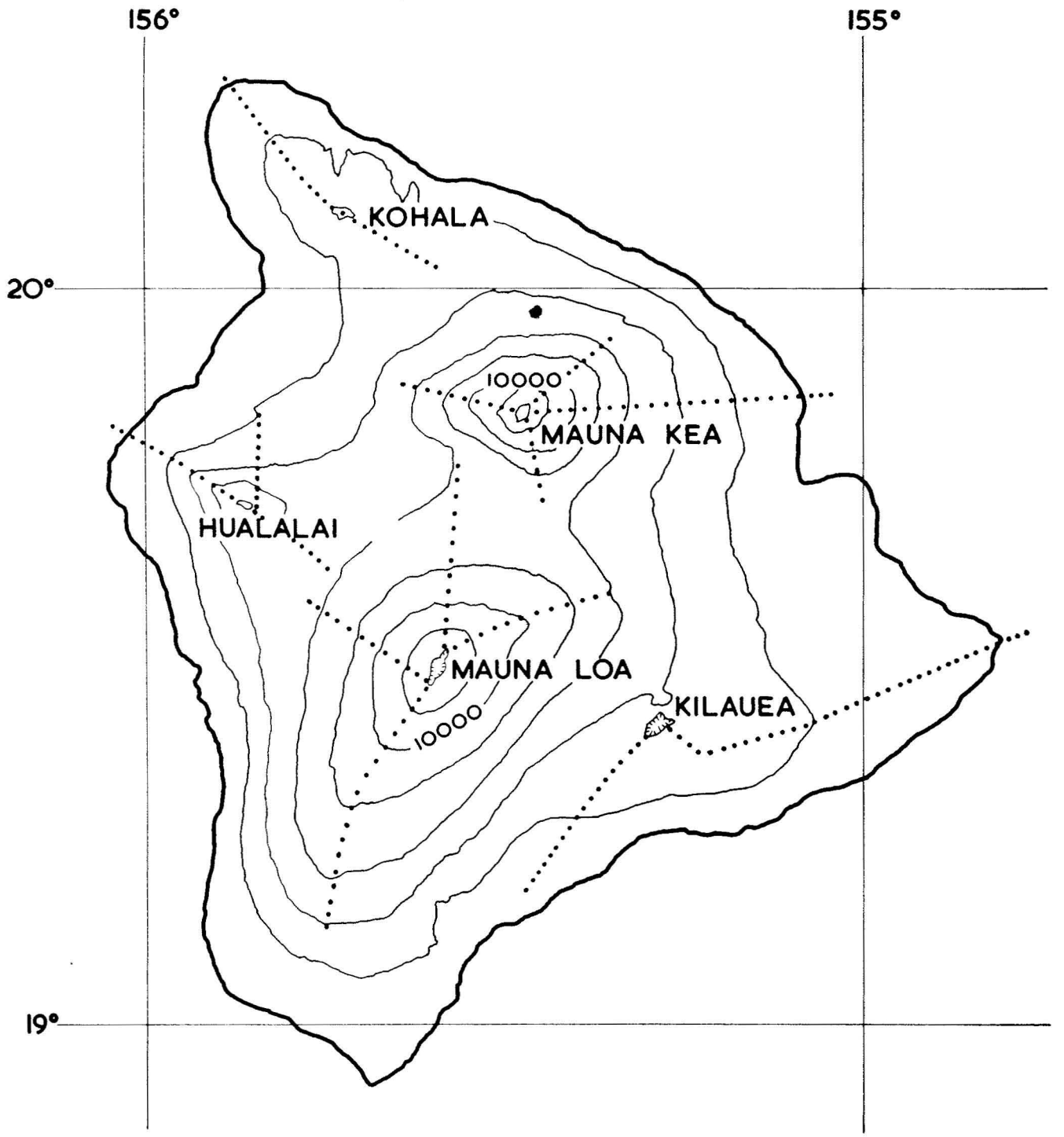


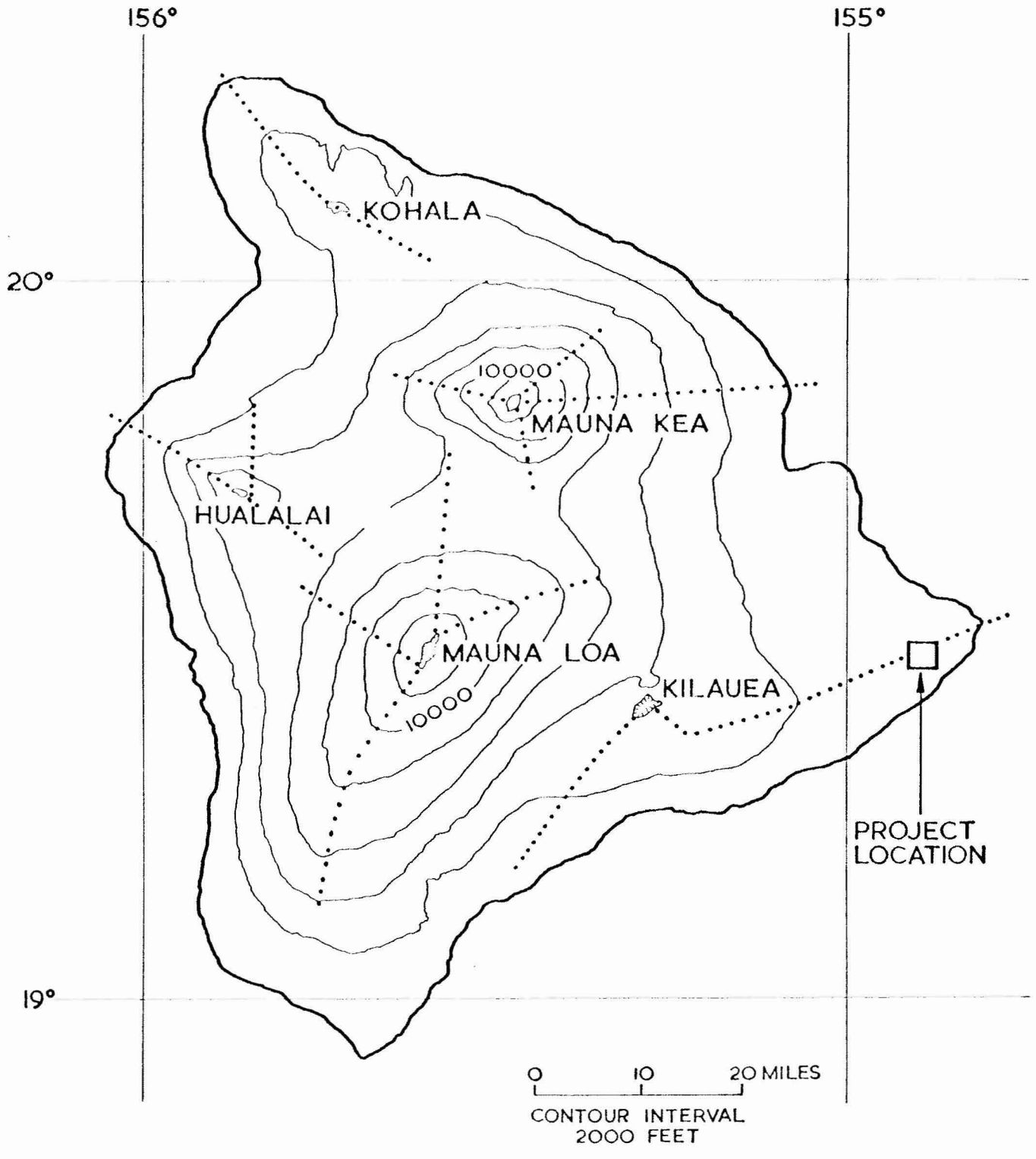
Hawaii Geothermal Project Drilling Plan

HAWAII GEOTHERMAL PROJECT

DRILLING OF THE DEEP EXPLORATION WELL ON THE ISLAND OF HAWAII

Drilling Plan

Prepared by
KINGSTON REYNOLDS THOM & ALLARDICE LIMITED
44 Wakefield Street Auckland New Zealand
August 1975



LOCATION OF WELL

PROGRAM DESCRIPTION

This deep exploration well is to be drilled for the University of Hawaii under authority of and funding by the Energy Research and Development Administration and the State of Hawaii.

The drilling site, which is shown on the enclosed maps, is located approximately 600 ft above sea level. A freshwater layer may be encountered some 10 ft above sea level and extending about 400 ft below it.

Surface conditions show a very broken crust of lava which will be underlain by lava of varying degrees of porosity, possibly also with lava tubes. The broken material will be cleared away, the surface graded to a suitable fall and blinded with crushed rock. The crushed rock shall have sufficient fine material to seal the surface and prevent the percolation of rain water, which would be transformed into steam as the well heats up.

As it is expected that hot conditions will be encountered at some point in the drilling the casing program included in this Drilling Plan is designed to minimise the risk of high formation pressures being released up the open hole and transferred laterally through incompetent rock. A four casing program has been selected with a slotted liner below the production casing.

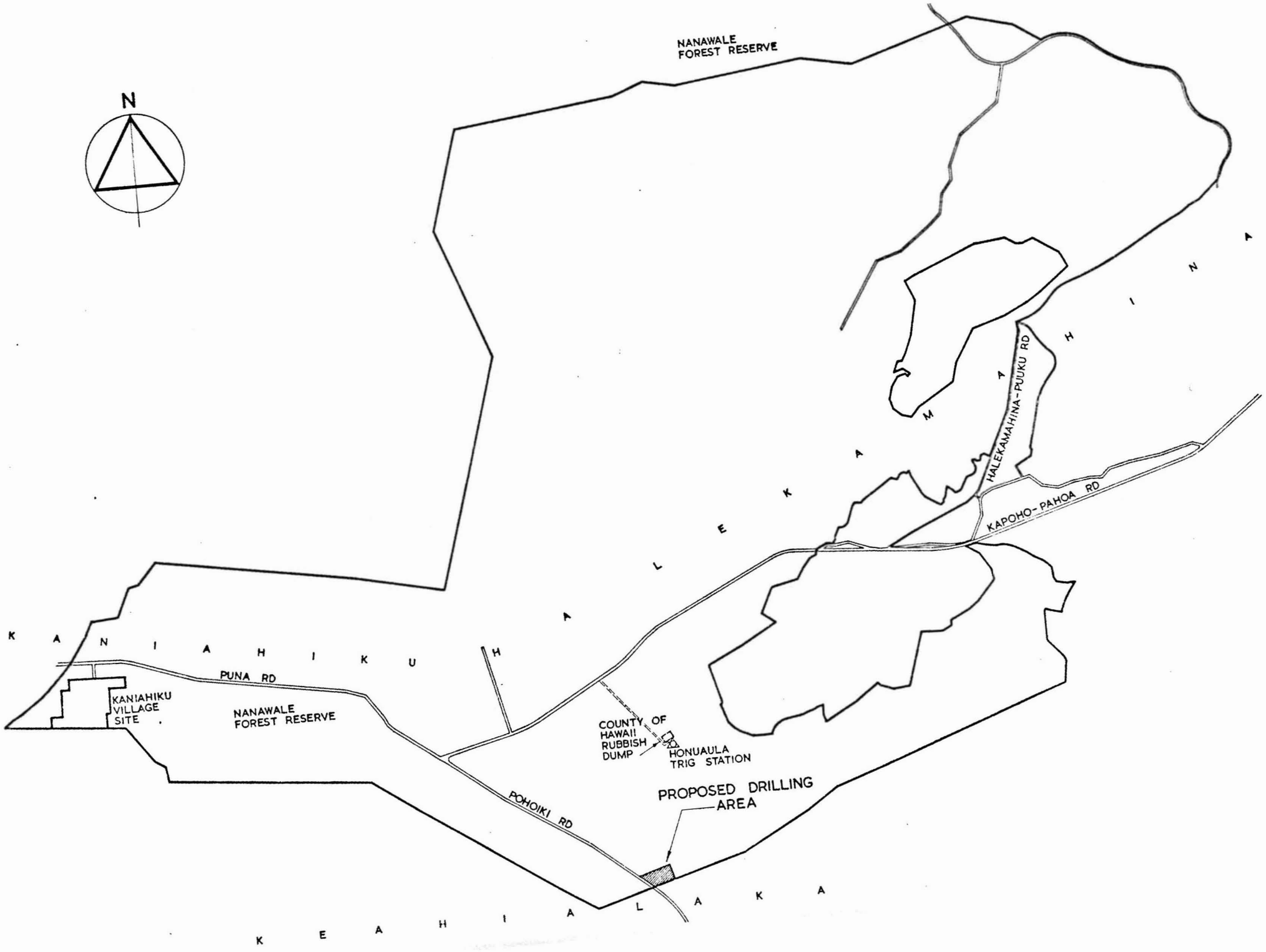
Conductor pipe	30"	to	12 ft
Surface casing	20"	to	400 ft
Anchor casing	13-3/8"	to	1000 ft
Production casing	9-5/8"	to	2500 ft
Liner	7-5/8"	to	6000 ft

Drilling is to be by rotary drilling rig using mud as the drilling fluid. Drilling conditions will most certainly be difficult. The use of pilot holes and hole openers, and additional drill collars, should overcome most penetration problems. The greater difficulty will be in maintaining circulation. In geothermal wells this has greater signifi-

cance than is normal in oil well or water well drilling. It is important to recover cuttings to guide coring decisions but if mud circulation cannot be maintained then probably grout return cannot be obtained during cementing operations. It is essential to have a completely filled annulus between casing strings or casing failure will result when the well heats up. For these reasons considerable effort will be made to seal off loss circulation zones.

Special attention will be given to cementing procedures and a specification of the method to be adopted is included in this Drilling Plan.

The University of Hawaii will appoint to the project a Drilling Manager and a Geologist who will supervise the drilling of the well through the Contractor. They will offer guidance and assistance to the Contractor, but in no way will this relieve the Contractor of the responsibility for the drilling operations. The Contractor is required to provide at all times supervision by a competent toolpusher, and skilled crews experienced in the operation of a drilling rig of this scale.


N
NANAWALE FOREST RESERVE
HALEKAMAHINA-PUUKU RD
KAPOHO-PAHOA RD
KANIAHIKU VILLAGE SITE
PUNA RD
NANAWALE FOREST RESERVE
COUNTY OF HAWAII RUBBISH DUMP
HONUAULA TRIG STATION
POHOIKI RD
PROPOSED DRILLING AREA
KEAHIALAKA

PRE-DRILLING SITE ACTIVITIES

1. Before releasing the site to the Contractor, the University of Hawaii will

   a) Establish rights of way and construct roading into the drilling area.

   b) Clear and grade drilling and surrounding area.

   c) Construct a reject mud and grout pit approximately 60 ft x 60 ft x 6 ft deep. This can be constructed by forming a depression with a bulldozer, blinding the surface with graded crushed rock and sand.

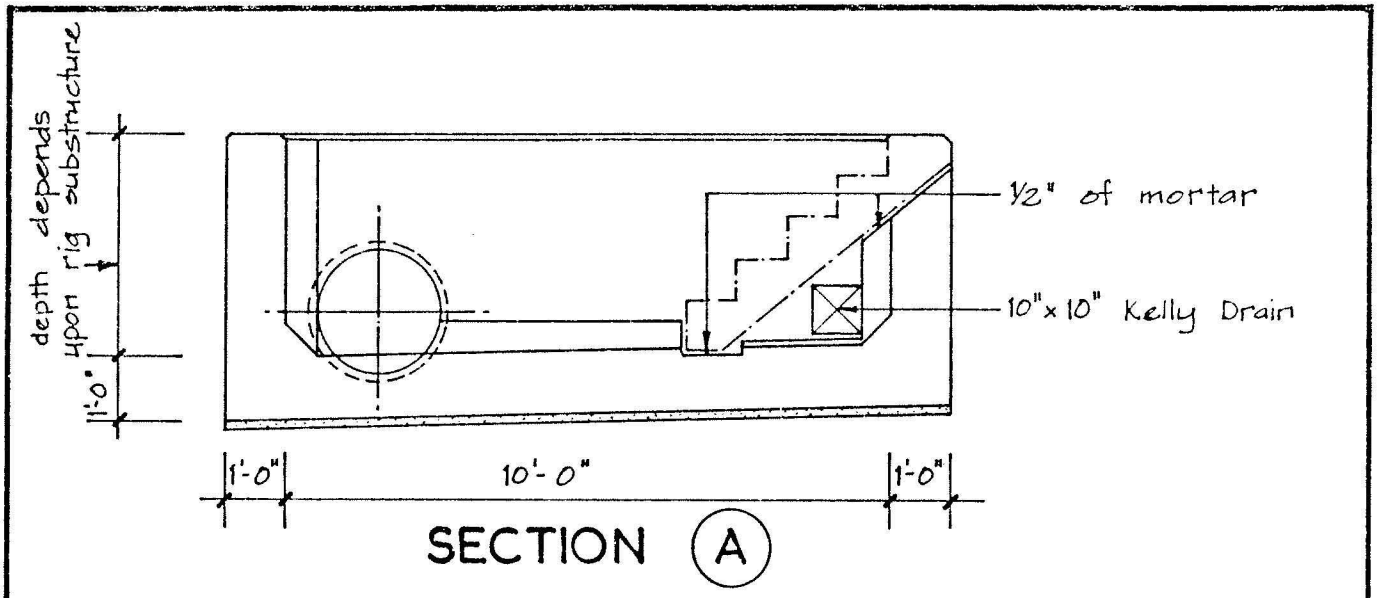
   d) Provide a site office for the drilling manager and geologist. This shall consist of two rooms, one of which shall be used as an office and the adjoining room as a technician's workshop, storage for instruments and storage of drill cuttings and cores. The office shall be provided with electric light, power and telephone, and the workshop with power and light and a laboratory type sink with water connection.

   e) Construct a drilling cellar 15 ft x 12 ft and to a depth appropriate for the rig sub-structure, set in a 30 inch OD conductor pipe to a depth of 12 ft.

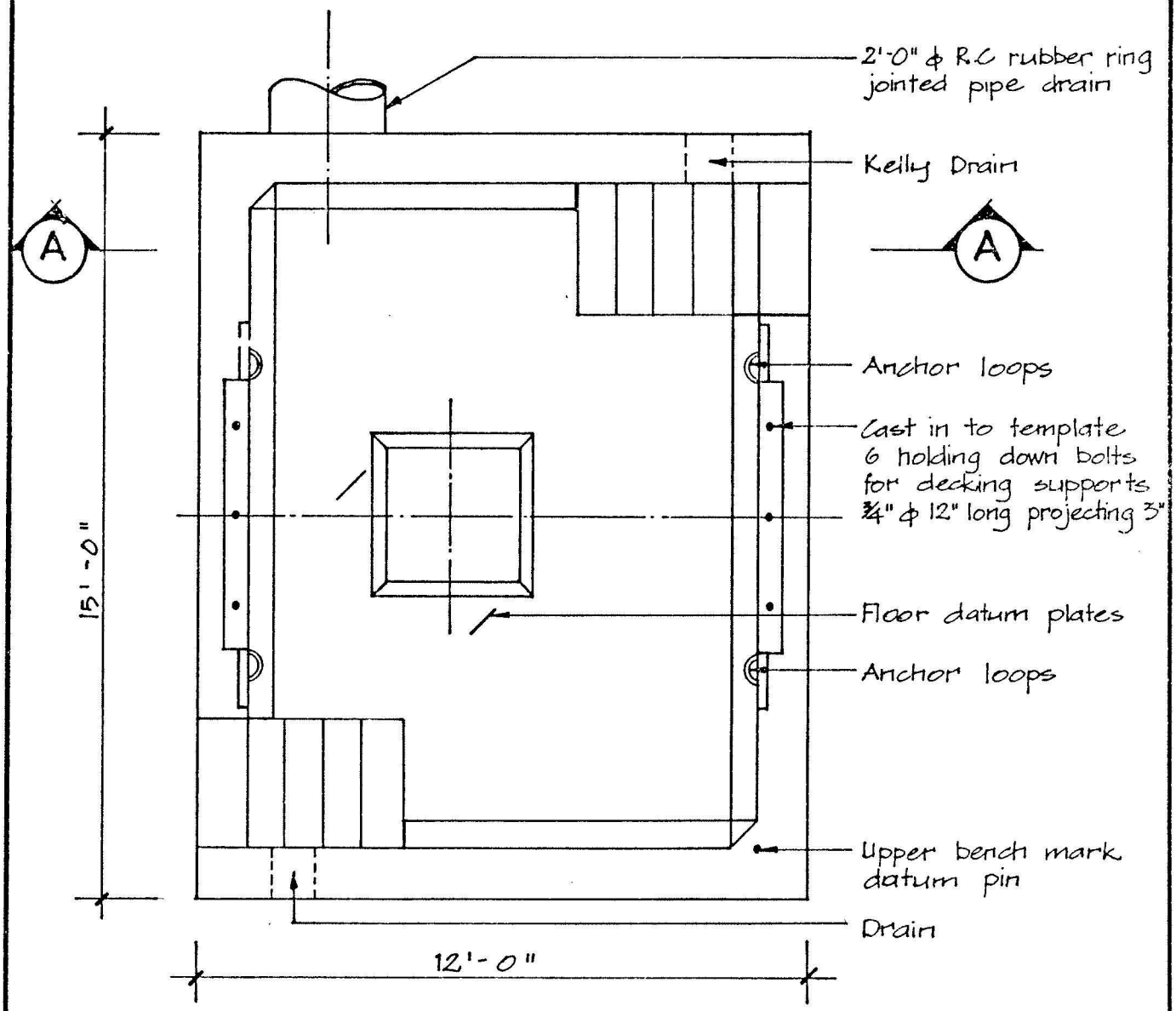
2. On taking over the site, the Contractor will

   a) Prepare working areas:
   Spread crushed rock over the working areas.

   b) Construct water reservoir:
   Form and maintain a reservoir of a minimum capacity of 180,000 US gallons of water. This can be constructed by forming a depression with a bulldozer; blinding the surface with graded, crushed rock and sand; and sealing with a polyethylene or similar liner. The control of the expenditure on this item will be in the hands of the University of Hawaii or its agent.



SECTION (A)



PLAN

HAWAII GEOTHERMAL PROJECT

3 FT. CELLAR

Kingston Reynolds Thom & Allardice
architects engineers planners and quantity surveyors

Box 5348 Auckland, Box 3582 Wellington, N.Z.

SCALES: N.T.S.

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2018	G 10	

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c) Provide fences:
The Contractor will provide and maintain adequate fences around the site.

d) Provide site offices:
The Contractor will provide site offices for his own operations.

e) Provide water and sanitation:
The Contractor will provide potable water for drinking and cooking. Chemical or standard toilets are to be provided and serviced as required.

f) Provide power:
The Contractor will provide rig and site power and lighting, either by portable generator or by mains connection and standby generator.

g) Provide sheds:
The Contractor will provide storage sheds for mud etc., cement, bits, casing hardware etc., and workshops for the rig mechanic.

h) Provide fuel:
The Contractor will provide diesel storage tanks of 3,000 gallons capacity. Diesel may be required as a mud additive as well as for the rig fuel.

3. Drilling materials:

The Contractor will call competitive quotations for the supply of drilling materials, casing, casing hardware, bits, wellhead etc. Acceptance of quotations shall be on the basis of price, quality and delivery and shall be subject to the prior approval of the University of Hawaii or its agent. Items up to $5,000 in value may be purchased by the Contractor without prior reference to the University or its agent.

Approximate quantities of materials are as follows:

Description	Quantity	Unit
CASING		
Surface casing 20", API grade 5L line pipe, bevelled for welding	400	feet
Anchor casing 13-3/8" K55 54.5 lb/ft buttress thread	1,000	feet
Production casing 9-5/8" K55 43.5 lb/ft buttress thread	2,500	feet
Liner casing flush 7-5/8" K55 26.4 lb/ft slotted (as per drawing) 8 slots/ft	3,460	feet
Liner casing flush 7-5/8" K55 26.4 lb/ft plain	40	feet
Centralisers, 18" casing	7	each
Centralisers, 13-3/8" casing (every 90 ft)	12	each
Centralisers, 9-5/8" casing (every 90 ft)	26	each
Shoes, 18" casing (coupling trimmed)	1	each
Shoes, 13-3/8" casing	1	each
Shoes, 9-5/8" casing	1	each
Float collars, 13-3/8" casing	1	each
Float collars, 9-5/8" casing	1	each
Stage cementer and plugs for 9-5/8" casing (including metal petal baskets)	1	each
J-slots and liner setter	1	each
Stop rings for 18"	7	each
" " " 13-3/8"	12	each
" " " 9-5/8"	26	each
Cementing travelling plugs (top and bottom), for 18" top	1	each
bottom	1	each
" " 13-3/8" top	1	each
bottom	1	each
" " 9-5/8" top	1	each
bottom	1	each

Description	Quantity	Unit
WELLHEAD EQUIPMENT		
Casing head flange (companion type)	1	each
Expansion spool and seal ring	1	each
Through conduit valve and two seal rings, 10" x 900 WKM	1	each
Flanged Tee and two seal rings	1	each
Flanged gate valve and one seal ring 10" x 600	2	each
Casing 9-5/8" K55 43.5 lb/ft	40	feet
Bypass and blowing spool flanges 10" 600 series	4	each
Side valves (wedge gate) 2" 1500 series and two seal rings	1	each
Stud bolts and two nuts		
7/8" x 5-3/4"	18	each
1¼" x 8½"	70	each
1-3/8" x 9½"	35	each
1-3/8" x 10"	24	each
Local fabrication of pipework for discharge testing.		
DRILLING MATERIALS		
Cement	322	s.tons
Cement retarder (HR4)	0.25	s.tons
Bentonite	200	s.tons
Lignite	0.7	s.tons
Lignosulphonate (Q. Broxin)	1.4	s.tons
C.M.C.	1.5	s.tons
L.C.M. (cellophane)	2	s.tons
L.C.M. (mica)	0.5	s.tons
L.C.M. (cotton seed hulls or similar)	10	s.tons
Barytes	20	s.tons
Caustic soda	2	s.tons

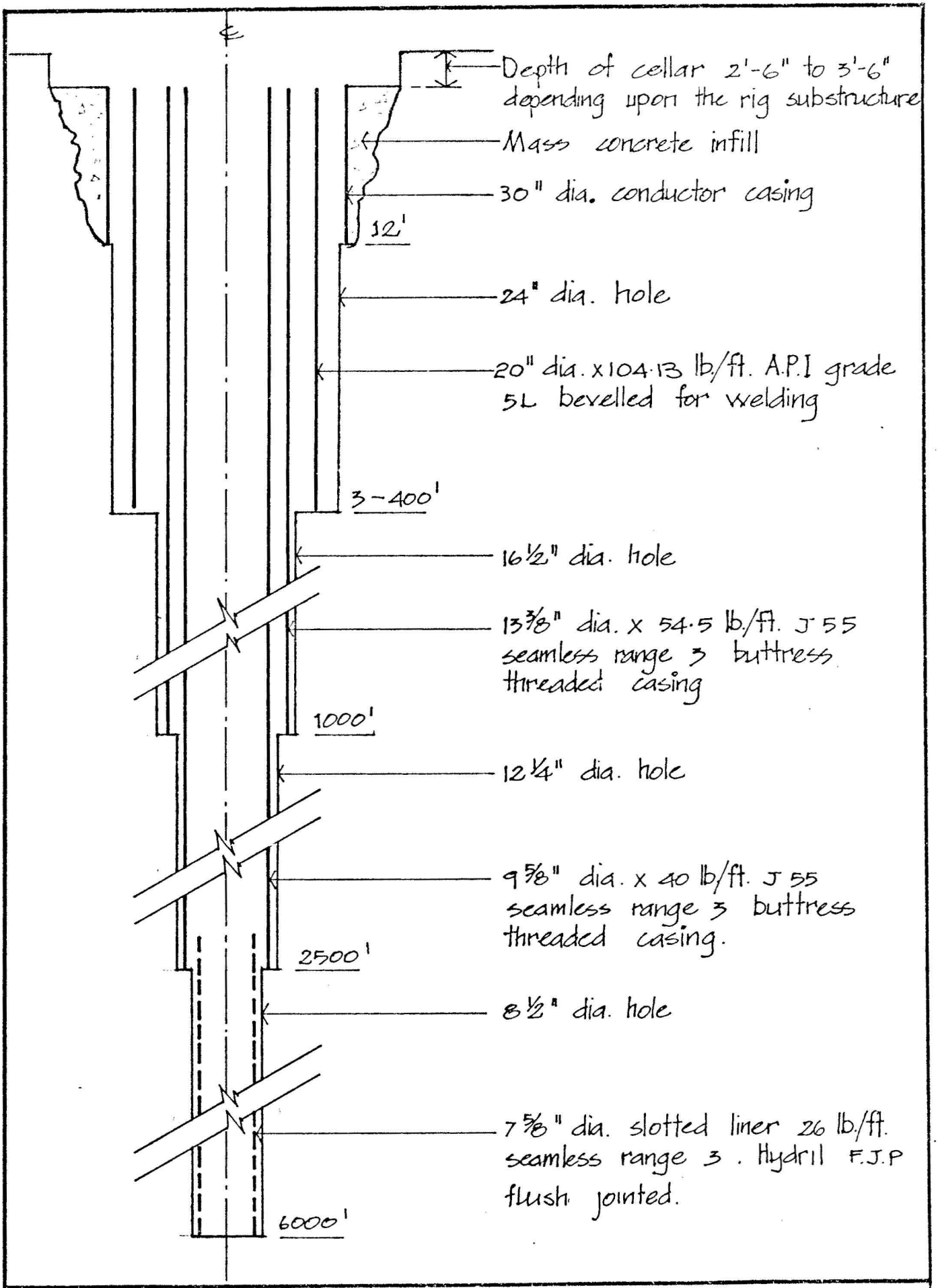
Description	Quantity	Unit
Tannin	3	s.tons
Sodium bicarbonate	1	s.tons
Diesel oil		gallons
Air entraining agent	72	gallons

BITS

Hole opener, Baker Lockomatic or equivalent, to open to 24"		1	each
Spare cutters, hard formation		1	set
Hole opener, Smith or equivalent to open to 12¼", 15" and 17"		1	each
Spare cutters, hard formation:	12¼"	6	set
	15"	1	set
	17"	2	set
9-7/8" bits, Smith L4, Hughes Regular tricone or equivalent		21	each
8½" bits, Smith L4, Regular tricone or equivalent		35	each
Diamond core heads		3	each
Regular core bits and catchers		8	each

Surplus materials:

Surplus materials in stock on completion of the drilling shall be sold or, by arrangement, returned to the suppliers, and the proceeds credited to the University of Hawaii.



HAWAII GEOTHERMAL PROJECT

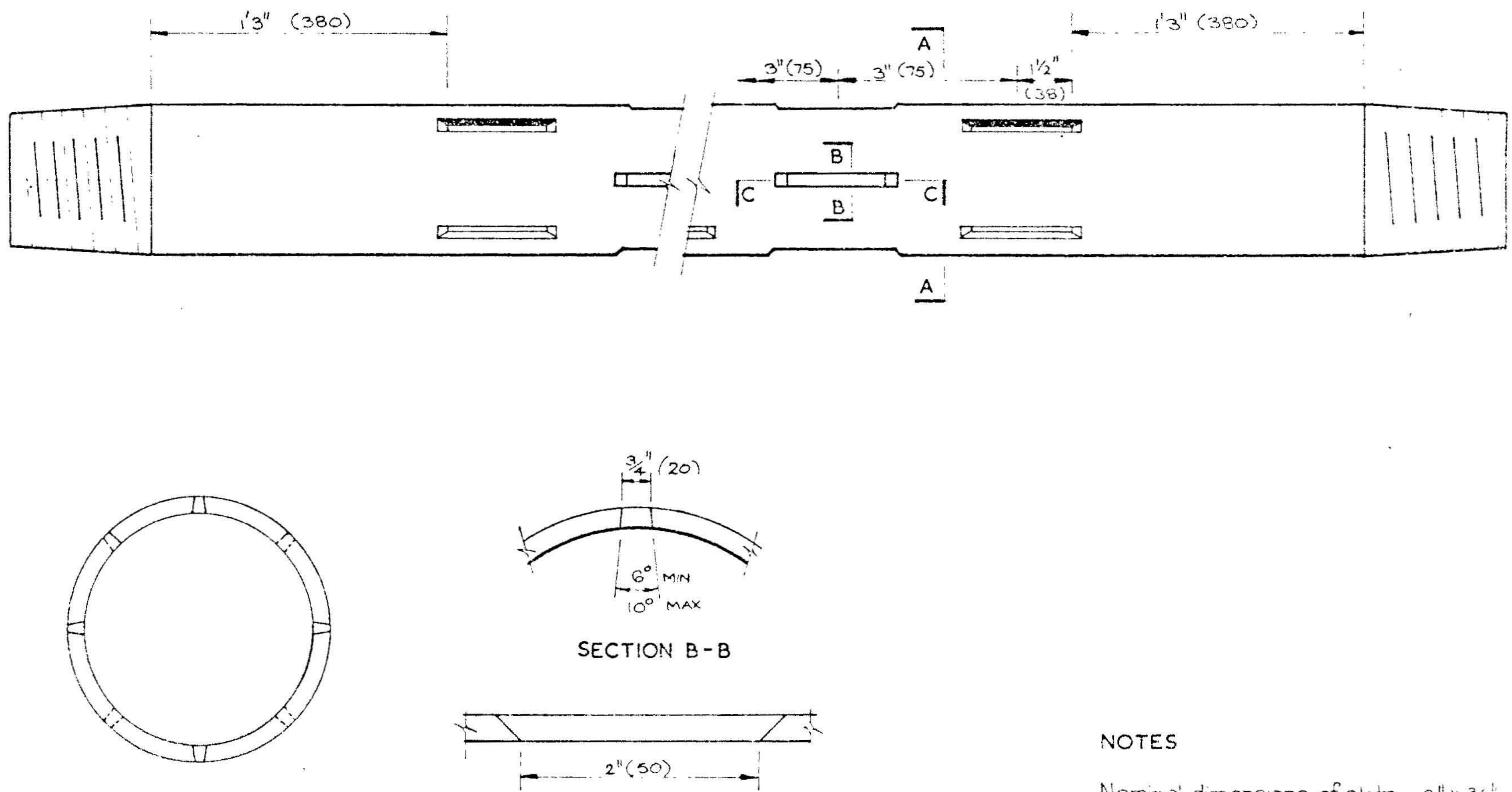
Kingston Reynolds Thom & Allardice
architects engineers planners and quantity surveyors

Box 5348 Auckland, Box 3582 Wellington, N.Z.

SCALES: ¾" & 100' = 1'-0"

PROJECT	DRAWING	REVISION
2018	G 1	

DATE JULY '75 DRAWN R. KHOO CHK'D



SECTION A-A

SECTION B-B

SECTION C-C

NOTES

Nominal dimensions of slots - 2" x 3/4" (50 x 20)

Minimum area of slot - 1.5 sq in (9.30 [illegible] mm²)

N° of slots per foot - 8

Area of slots per foot - 24 sq in. (15,480 mm²)

Minor variations to slot cutting details [illegible] must accompany tenders

Metric equivalent of dimensions given in [illegible]

Contractor shall check all dimensions against job before starting

[illegible] Reynolds Thom & Allardice Limited
[illegible] engineers planners and quantity surveyors
Auckland, Wellington & Christchurch N.Z.
[illegible] Reynolds Thom & Allardice Limited

HAWAII GEOTHERMAL PROJECT

7 5/8" (194 mm) BUTTRESS CASING - SLOTTING DETAILS

DESIGNED	SCALES
DRAWN	PROJECT / DRAWING
TRACED	2018 / G II
CHECKED	
DATE	

DRILLING EQUIPMENT

Drilling rig:

The Contractor is to provide a drilling rig of sufficient capacity to drill to 6,000 ft. The draw-works, mast, swivel and crown block all are to be appropriate for the task. The mast and hook load capacity are to approximate 250,000 lbs. Two slush pumps are to be provided, one as standby. Each is to be approximately equivalent to a C250 which is 7¼" x 15" rated at 370 maximum input H.P. at 65 R.P.M., 615 gallons/minute with 7" liner, 875 p.s.i. maximum discharge pressure. The drill string is to be 4½" or 5".

All drill pipe and drill collars are to be inspected by accepted methods and inspection certificates made available.

Drilling recorder:

An automatic drilling recorder will be used to record penetration rate, weight and pump pressure.

Cooling tower:

A cooling tower is to be provided with internal wooden slat frames and top mounted forced draught 10 H.P. exhauster fan; and with a heat extraction of 6 million BTUs/hour at entry temperature 42°C and 13½ million BTUs/hour at 66°C.

DRILLING PROGRAM

1. 30" OD conductor pipe will be set to a depth of 12 ft in an excavated hole and cemented in.

2. Drill 9-7/8" dia. pilot hole to a depth of 400 ft with mud circulation using 8" drill collars. Open out to 24" using hole opener in two runs. Run and cement 20" casing. Drill out cement after at least 12 hours.

3. Drill 9-7/8" dia. pilot hole to a depth of 1,000 ft. Using a hole opener, open out to 15" and 17" in two runs. Run and cement 13-3/8" dia. casing with casing landed so the CHF is 1.7 ft above cellar floor.

   Erect wellhead as per stage I of drawing, drill out cement after 12 hours and pressure test to 1000 p.s.i.g. above float collar and 15 ft above shoe.

4. Drill 9-7/8" dia. pilot hole using 8" drill collars to a depth of 2,500 ft. Open out to 12¼" dia. with mud circulation. Run and cement 9-5/8" dia. casing. Cut off casing 2" above 13-3/8" CHF and erect wellhead as per stage II of drawing. Drill out cement and pressure test to 1000 p.s.i.g. above float collar and 15 ft above shoe.

5. Drill 8½" dia. hole using 6¼" drill collars to 3,500 ft with mud circulation, changing to water after first major loss of circulation. Clean out hole, carry out completion tests and then shut off water supply.

6. If the decision is made by the University of Hawaii to complete the hole at this depth, run 7-5/8" slotted Hydril F-J casing from hole bottom to inside of 9-5/8" casing shoe with one length of plain casing on top, and set on bottom using a J-slot adaptor.

   If full circulation has been maintained, wash through liner with jet washing tool to remove mud wall cake.

7. If well cannot be quenched set Hydril Retrievable Bridge Plug and fit master valve and side valves as per drawing.

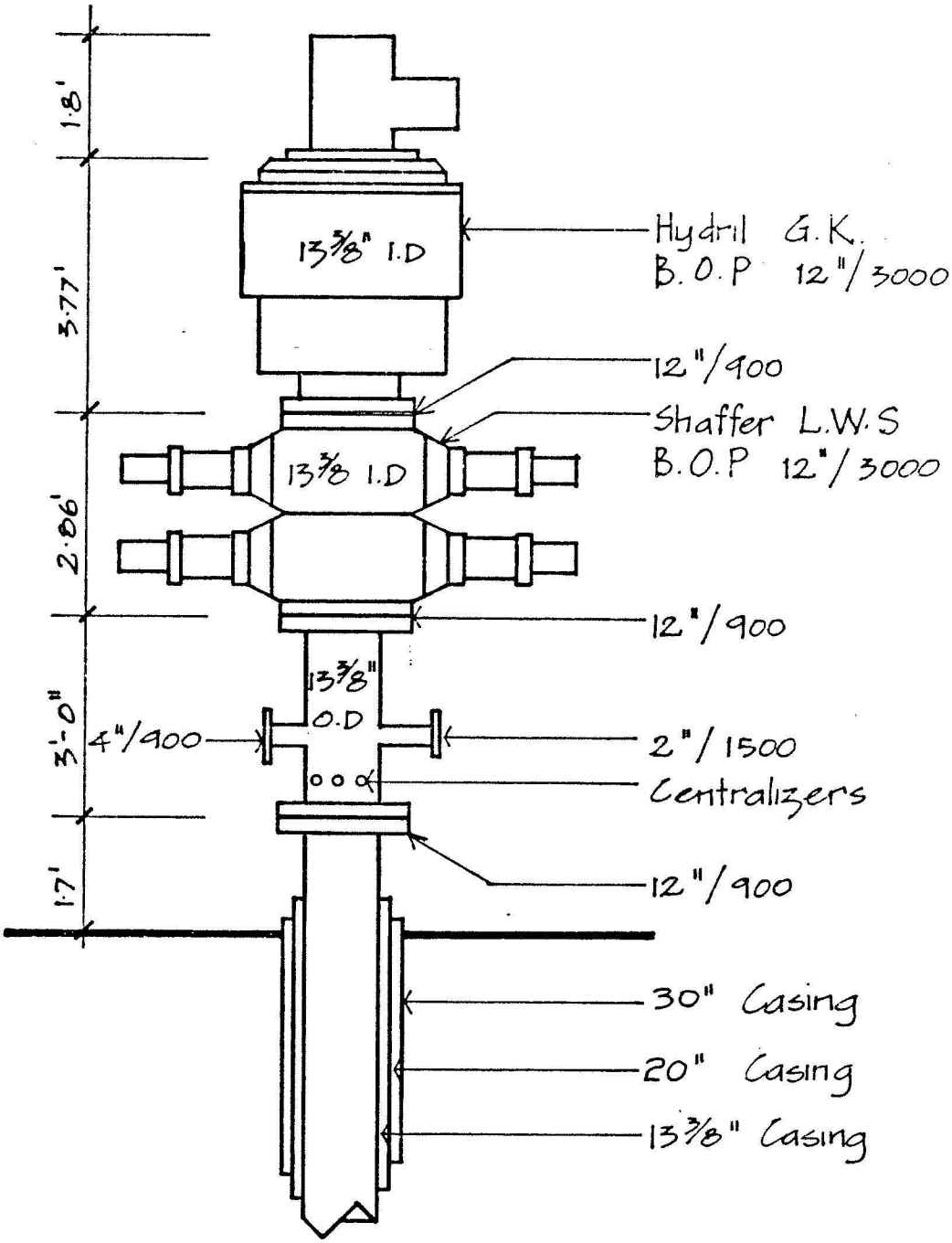
8. Test well.

9. Rig down.

Note: Centralisers for 9-5/8" and 13-3/8" casing to be set 5 ft above casing shoe and approximately at 90 ft spacing. Also at 10 ft above outer casing shoe.

If a decision is taken to drill on to 6,000 ft, the liner will not be run. Loss zones will be sealed if possible and the hole drilled with mud until further loss zones are encountered near 6,000 ft and the well completed as before.

If the loss zones cannot be sealed, drill on with water using mud slugs to clear cuttings.



13 3/8" Casing landed
Drilling 12 1/4"

HAWAII GEOTHERMAL PROJECT

WELLHEAD
STAGE 1

Kingston Reynolds Thom & Allardice
architects engineers planners and quantity surveyors

Box 5348 Auckland, Box 3582 Wellington, N.Z.

SCALES: 3/8" = 1'-0"

PROJECT	DRAWING	REVISION
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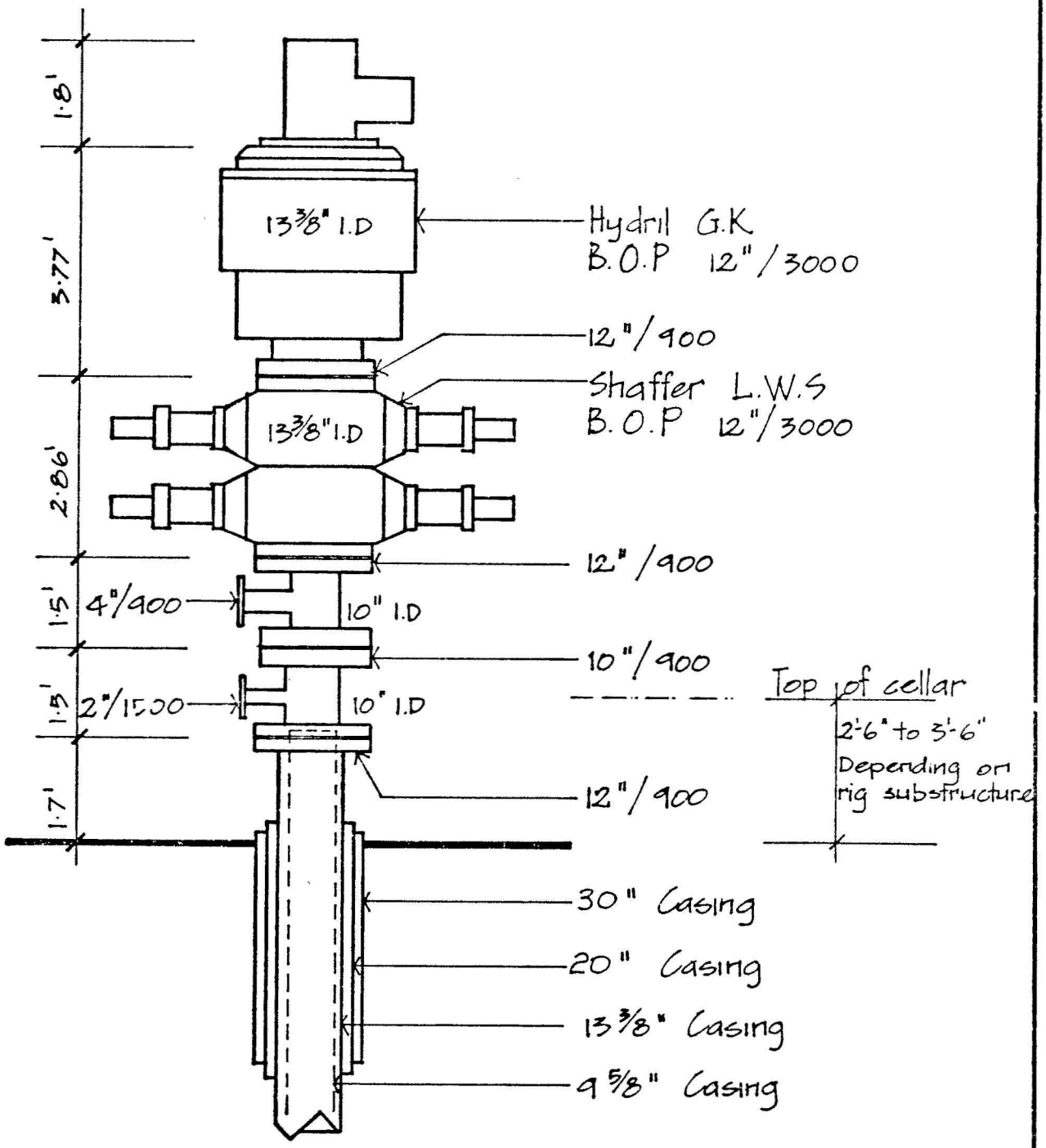

9 5/8" Casing landed
Drilling 8 1/2"

HAWAII GEOTHERMAL PROJECT

WELLHEAD
STAGE 2

Kingston Reynolds Thom & Allardice
architects engineers planners and quantity surveyors

Box 5348 Auckland, Box 3582 Wellington, N.Z.

SCALES: 3/8" = 1'-0"

PROJECT	DRAWING	REVISION
2018	G 3	

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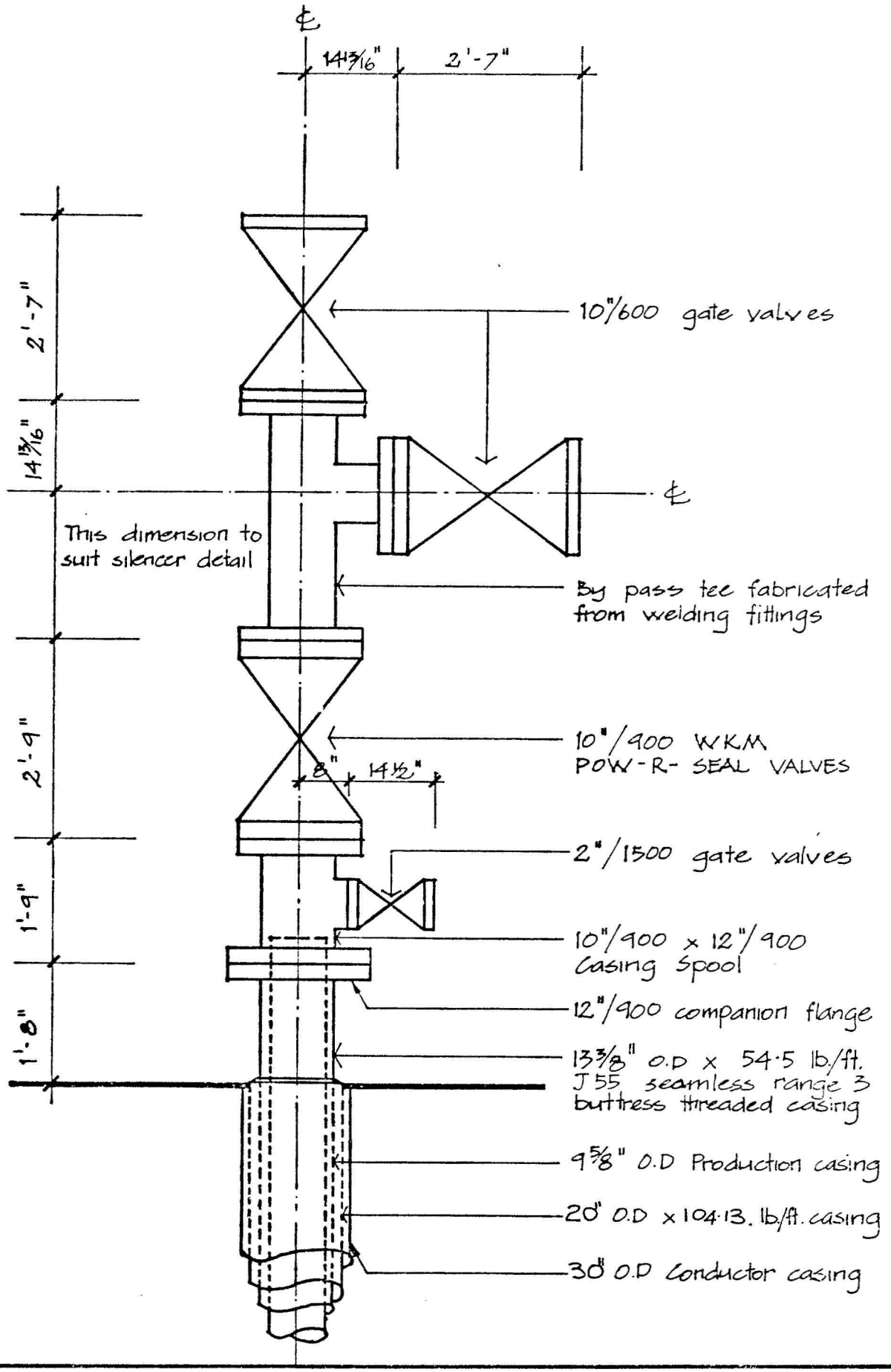

HAWAII GEOTHERMAL PROJECT

WELLHEAD STAGE 3

Kingston Reynolds Thom & Allardice
architects engineers planners and quantity surveyors

Box 5348 Auckland , Box 3582 Wellington, N.Z.

SCALES: ½" = 1'-0"

PROJECT	DRAWING	REVISION
2018	G 4	

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ABANDONMENT OF WELL

Should impenetrable or unfavourable conditions be encountered, the University may at its discretion direct that the hole be abandoned. Should this decision be taken within the first thirty days of the Contractor's operations, and if drilling is not resumed at an alternative site, then the Contractor's equipment hire rate will be payable for a minimum of thirty days.

CEMENTING OF CASING

It is important to ensure a continuous cement bond over the entire length of the casing string, and essential to completely fill the annulus between casing strings.

Cementing procedures will be as follows:

1. Circulate after running casing until return temperature of mud reduces to $50^{o}C$.

2. Pump away 500 gallons of water then insert bottom travelling plug.

3. Pump away 1200 gallons of 75 p.c.f. lightweight grout and follow immediately with a quantity of 105-108 p.c.f. grout equal to the sum of twice casing to casing annulus volume plus three times casing to open hole annulus volume plus casing contents; or until there is a return of "heavy weight" grout up the annulus.

4. Insert top travelling plug and displace casing contents or until plug sits on the float collar.

5. If "heavy weight" return is not attained pump similar grout under pressure continuously back down the annulus with sufficient to clear the casing to casing annulus and continue with batch mixing with increasing time intervals until a pressure build up occurs.

6. The above program may have to be modified depending on the success of maintaining full circulation during drilling operations. In particular it may be necessary if circulation is lost during either drilling or cementing, to displace a more limited quantity through the casing and to then revert to a continuous cementing operation back down the annulus.

7. Casing is to be centralised in the appropriate spool with centralising studs before the initial set of the cement grout takes place.

Cement grout specification:

Density	105-108 p.c.f.
Bentonite (Wyoming)	1½ to 2% by weight cement up to 4 oz/bag of cement.
Water cement ratio	0.5
Yield	8.25 Imp.gallons/93 lb bag cement
Retarder HR4	0.2 to 0.4% weight of cement depending on temperature conditions.

Reciprocating of casing:

During cementing operations casing will be reciprocated until a return of grout is obtained or an initial set has taken place.

Continuous operation:

Cementing operations shall be continuous except for surface casing when batch mixing would be used.

DAILY DRILLING REPORT

The Contractor will provide the Drilling Manager with a daily drilling report. Report forms incorporating the required information will be provided by the Drilling Manager before the drilling commences.

INSPECTED AND/OR TESTED (Initial each item)

CROWN BLOCK: ..... B.O.P. and GATE: .....

PLATFORM: .....

SAFETY SLIDE: .....

HEIGHT: KELLY DRIVE TO CASING HEAD FLANGE ..... Ft.

PROJECT: .....

DRILLING LOG

ALL DEPTHS BELOW KELLY DRIVE DATUM (UNLESS MARKED OTHERWISE)

BORE: .....

DATE: .....

SHIFT: ..... To .....

DRILLED DEPTH: .....

Time (on the hour)									
Depth at									
① Operation									
Weight 1,000 lb									
Rotary r.p.m.									
Rotary Torque ft/lbs									
Circ. Pump No. ..... Type ..... Liner size ..... Strokes/Min. P.S.I.									
FLOWS In g.p.m.									
Out g.p.m.									
Loss g.p.m.									
Mud in storage gals									
Temperatures In °C									
Out °C									
Mud Weight lb/cu ft									
Viscosity secs									
pH									
Water loss cc									
Filter cake 1/32"									
Sand %									

DRILLING ASSEMBLY AT END OF SHIFT	Size in.	No.	Total Length Feet	Tenths
Down hole				
Drill pipe				
Doubles				
Singles				
Drill collars				
Reamer				
N.R.V. and Bit Subs				
Bit or core Barrel				
Total D.P. and tools				
Kelly down				
Depth of hole				

PLANT	HOURS WORKING
Draw works	
pump 1	
pump 2	
pump 3	
Generating plant	
Mud screens	
B.O.P. accumulator	
Air compressor/s	
Cooling tower motor	
Mission 1	
Mission 2	
Mission 3	

MECHANICAL FAULTS

ELECT. INITIALS .....

FITTER'S INITIALS .....

Bit make	Size	Type	Serial No.	Jets and Area	Cum. Ft. Drilled	Hours	Bit Wear [0 to 4 Scale]
				× " □ "			T. B. O.
				× " □ "			T. B. O.

Core bits Size, make, etc.

MATERIAL		Used during shift	Received during shift	On hand at end of shift
Bentonite	bags			
Spersene	bags			
XP 20	bags			
Tannin	bags			
Caustic soda	drums			
C.M.C.	bags			
Barytes	bags			
Soda bicarbonate	bags			
Cellophane	bales			
Mica	bags			
Diesel in Mud	gals.			

MATERIAL		Used during shift	Received during shift	On hand at end of shift
Diesel	gals.			
Water	gals.			
Cement	bags			
Pozzolan	bags			
Perlite	bags			
Plastex	drums			
HR 4	bags			
Calcium chloride	drums			
②				
Casing	in.			
Casing	in.			
Drill pipe	in. lengths			

Casing shoe depth ..... ' KD Drill collar weight ..... lbs Drill string weight ..... lbs

Circulation Stopped	From
	To
Maximum temperature after stoppage °C	
Time of maximum	
Time of observed circulation loss	
Depth of loss ft.	

③ DEVIATION Johnson/Eastman/Totco

Depth	Vert. Dev.	Direction

FORMATION From	To	Soft, Med., Hard, Rough or Smooth	Interpretation

CORE RECOVERY Depths	Ft.

Driller		Helper	
Derrickman		Helper	
Helper		Helper	

TIME	REMARKS AND DETAILS OF WORK DONE:

TIME	TESTING etc. (Temperature runs, mud sampled, Engineer's observations)	Initials

① Drilling = D. Drilling cement = G. Coring = C. Reaming = R. ② Specify other materials. ③ Delete types not used.

Overseer's signature: .....

TESTING

Testing procedures are described in another document. In summary they consist of the following:

1. Particular attention will be given to recovery of cuttings.

2. Cores will be taken approximately every 300 ft but this will be related to bit changes. Additional cores will be taken if there is a change in formation or in zones of special geologic interest.

3. On completion of the well, the following tests will be carried out:

   a) Caliper run.

   b) Water loss run to identify zones of inflow.

   c) Permeability test at various pumping rates to establish permeability index.

   d) Temperature runs.

4. Further temperature runs will be carried out after rig has been removed and well is heating up. Chemical samples will be taken with a downhole sampling bottle.

5. If well will discharge, lip pressure and water quantities will be measured with flow diverted through a silencer.

6. No drill stem tests will be taken.

7. Electric logging will be considered only when well is nearing completion. A decision whether to log will depend on the budget and the temperature of the well.

SITE CLEAN-UP AND RESTORATION

Upon completion of drilling the Contractor will remove the drill rig and all rig associated equipment. The Contractor will dispose of drilling fluids and backfill the reject mud pit and the water reservoir, and restore the drilling area. All valves are to be securely locked in an open or shut position as directed by the University.