TRIP REPORT

VISIT TO CAMBODIA

23RD MAY - 21ST JUNE 92

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FOR: OXFAM - CAMBODIA

SUMMARY.

The Port-a-Rig has been successfully put into service with Oxfam Cambodia. With small field modifications it has achieved a small programme of drilling - encompassing typical PAT style sand & clay holes through to operating a hammer on holes into consolidated rock.

In comparison with the PAT rigs the Port-a-Rig has a longer drill stroke with larger diameter drillpipe - which has got to be an advantage when drilling deeper holes with centrifugal pumps. It is hoped the engineering will settle down to provide a long working life free of major maintenance. The depth limitation is based on circulating pump capacity and drillpipe diameter. To drill production holes regularly deeper than 30 metres a machine of size and capacity of the "Eureka Drill System" would be more appropriate

Any drilling operation has two essential ingredients the tools - the "Hardware" and the methods - the "software" and as with computers it is essential to match the two up correctly to accomplish a job of work.

Low technology drilling succeeds very well when relatively stable drilling conditions exist and it is possible to adopt a simple drilling technique from site to site - following a practical formula - any practical group of labourers can achieve good results.

The drilling conditions encountered in the North West of Cambodia cannot be described as stable ground, conditions vary quite considerably and the need to modify drilling techniques from hole to hole becomes essential. Rather than drill crews following a technique "by rote" they will be required to make technical judgements and they need to base these judgements on some sound principles of proven drilling technology.

The Khmers are technically very practical resourceful people with strong individual pride in what they can accomplish - ideal "driller" material - but they will benefit greatly from a base of education so that they can relate sound knowledge directly to the field conditions they are experiencing. They, with Oxfam support, have achieved considerable well production in very difficult circumstances, the important thing to do is to consolidate on this - train out the bad drilling practice and generally tune up and improve the overall performance. My recommendation would be to for Oxfam to produce a simple drilling technology handbook - translated into Kymer that could be introduced perhaps at some special training seminars to begin to improve the base of knowledge.

The Khmers also have all it takes in motivation to become "private drilling contractors" given appropriate equipment and source of materials they could very effectively increase the well count in Cambodia, at more efficent costs than direct NGO involvement and would of course be a permanent nucleus of water supply skill available to the country

There are some alternative drilling and well construction techniques that should be experimented with and will require some additional resources

My observations and recommendations now follow together with a daily diary notating the events of this short consultancy trip

SPECIFIC OBSERVATIONS & RECOMMENDATIONS

SHIPPING:

The Port-A-Rig had been packed up as condensed in volume as possible to attract the most favourable rate of airfreight - normally based per 1000kg or Metre Cube whichever is the greater - it is volume that wins this equation invariably unless you are looking at a consignment of razor blades or concrete. When the goods were received at Gatwick they were extensively repacked to reduce unit weights to under 80Kg to suit "Airline handling" presumably in Phnom Penh this re-packing exercise essentially doubling or even tripling the initial volume of the consignment with presumably a consequent tripling of the airfreight cost the shipment.

Without specific knowledge of this particular shipment I am practically surprised, looking at the level of business in Phnom Penh airport, by the 80Kg limitation per package and comment how convenient to airline profitability if it can persuade its clients to triple the volume of each consignment! At the very least it would pay the freighter to invest in the most rudimentary fork lift/ pallet handler to ship freight more efficiently. (I understand UNTAC are proposing to strengthen airport handling)

GENERAL TOOLS AND WELL DRILLING CONSUMABLES:

Our early days of rig operation were slowed in collecting together the essential trivia of a drilling operation. We needed buckets, a decent spade & Shovel, crowbar, jerry can for fuel, funnels, rope to tie down rig in pick-up truck, odd bits of surface casing to use as conductor casing, and daily trips to plumbing shops to get fittings top join pumps to hoses compressors to valves. Yes, we did finally get everything together after a fashion but it would also help the initial start up if these things had been partly supplied with the rig - particularly if it were to be employed in a region where these sorts of tools & items were in short supply.

Of immense use where the samples of drill fluid additive and foam that had been enclosed - whatever the destination a little room should be made for such samples so whatever the perceived drilling condition faced there would at least be enough of something to prove a technique will positively work.

To follow through this argument it would be worth putting together - on paper first, with a view to stock in the future, a kit of well lining materials and pumps selected to suit the drilling parameters of the Port-A-Rig. With careful choice it is possible to cover a wide range of construction options that would allow some trial holes to be fully completed, evaluated and produce water.

BOREHOLE DESIGN - CAMBODIA:

The price of the "minimalist" approach of low tech drilling rigs is that the drilling techniques want to be kept as simple and as conservative as possible. This will mean having to compromise on the scope of construction wherever possible - drilling a 4" hole rather than a 6" requires less than half the effort in terms of drilling pump or compressor.

The current Oxfam PAT drilling programme has discovered this ease of construction and has just implemented the insertion of 1.1/2" diameter Vietnamese manufactured .025mm slot 10% open area screen onto a 2"& 2.1/2" riser pipe. A local arrangement is then made to couple a Cambodian made cast iron hand pump onto India MK11 pistons working directly on the walls of the 2.1/2" riser pipe. The borehole construction is excellent the screen is good quality and can be used on rock through sand and if wells properly and easily developed will provide a long lasting water supply. The pumping method is not so good - with the money being saved on large diameter well casing and drilling equipment a little should be spent on a proven mass produced VLOM level hand pump that has the facility to remove piston and foot valve up the middle of its permanently installed 2" riser pipe. There are a handful of pumps with this facility my favourite being the "Afridev" - it works - probably has its faults but it has been around now for several years and the design is very precisely laid out as "public domain". Pumps can be bought complete or in bits with items being produced locally to suit any stage of a development programme. (Jeremy is active with other NGO's on selection and standardisation of required pumps)

One shortcoming of the direct drilled hole is that becomes impossible to monitor the water level and dynamic pumping level of a hole that is full of pump piston. In specific areas monitoring wells should be drilled - essentially the same construction but drilled with enough diameter to insert a 1" diameter plastic pipe strapped to the outside of the 2" pipe with a slotted length near well screen - depth measurement of water rest level and dynamic pumping level can then be made at will

DRILLING TECHNIQUES - CAMBODIA:

Without doubt the drill crews are very adept and skilled and have achieved a considerable amount with the equipment they have.

There are a number of specific shortcomings together with new drilling techniques introduced with the Port-A-rig that require addressing whilst using either the PAT or Port-A-Rig - indeed any rig in Cambodia.

1. Water Circulation Drilling.

The existing practice in Cambodia is to circulate clean water with no additives - particularly Bentonite - to avoid blocking off water bearing aquifers

To use just water with no additive requires a high up-hole velocity to keep the hole clean - this high up-hole velocity requires generation by a higher capacity pump than might normally be required and it is important to

maintain this velocity all the way to the hole bottom sometimes 50metres depth. In practice a single stage centrifugal pump is going to battle with this sort of duty - yes it will initially develop the flow but the deeper it goes the greater the pressure head loss in the drillpipe and borehole cuts the flow down considerably. Drillpipe internal diameter is a crucial factor in getting maximum pump drilling performance - the PAT drillpipe is uniformally 32mm bore - Port-A-Rig pipe is 38mm at tooljoint and 50mm in centre that little extra diameter will take the rig just that 20% - 30% deeper

Another effect of high up-hole velocity with water witnessed in Cambodia was the erosion of the borehole walls - creating an even larger diameter that requires yet more flow to successfully lift material to the surface.

To use clean water is in theory an admirable technique however in practice this water becomes quickly laden with natural clay particles which will cake on the aquifer walls just as tenaciously as the infamous bentonite - indeed when pressurised above by a clay collar formed by insufficient up hole velocity this particle laden fluid will be capable of flowing extensively into a fine sand aquifer and rendering it largely useless.

Use of a polymer drill fluid additive will keep the holes cleaner , requiring smaller pumps and if used correctly in conjunction with the right well development technique will always be a practical improvement allowing the drilling of better wells, deeper & easier. There is an estimated cost $40.00 per hole but it will make the very light equipment increase its performance

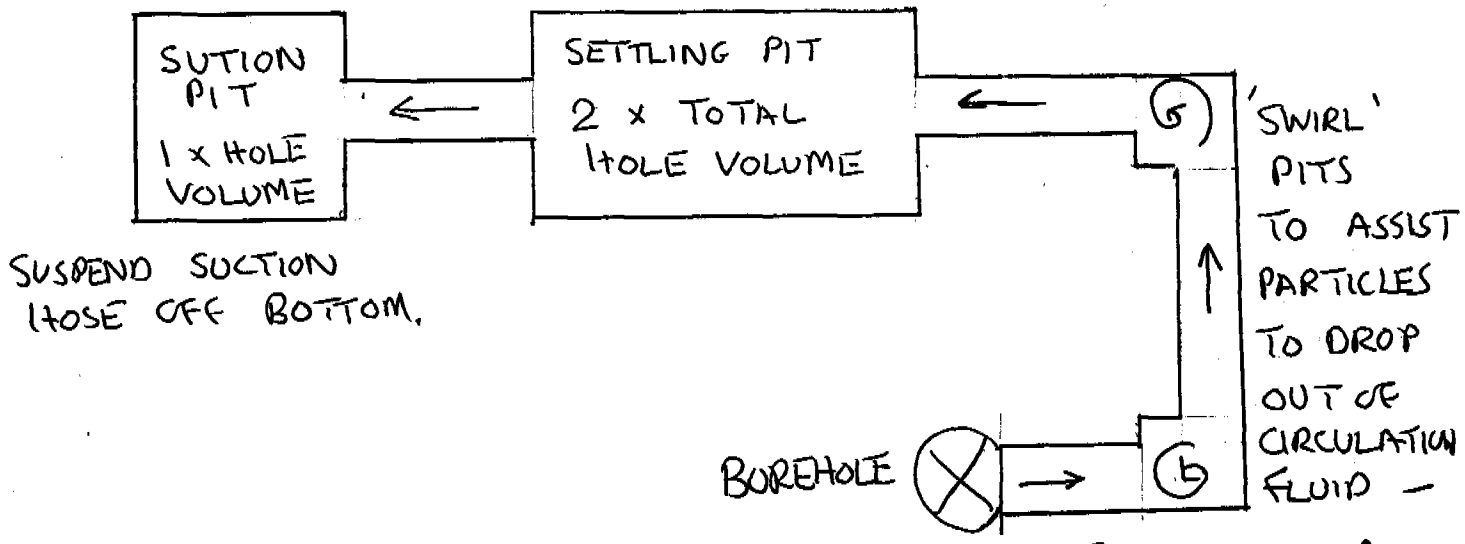
Centrifugal pumps performance can be improved by putting two pumps in series - pumping the delivery of one pump into the suction of the second pump - basically creating a two stage pump. This should only been done when flow from one pump had dropped off due to hole depth thus preventing too higher velocity eroding hole even wider and beware that pump 2 will be working at twice its normal body pressure so seal life will not be so good and generally pump wear will increase and any manufacturers pump warranty will be shot!

PARAMETERS FOR DRILLING WITH WATER/DRILL FLUID CIRCULATION				
Hole Dia & Depth	Hole volume Litres	Mud Pit Volume M/cube	Up-hole Water Flow gal/min	Up-hole Fluid Flow gal/min
4" x 20 metres	156	.5	80	40
4" x 30 metres	230	.7	80	40
4" x 40 metres	312	.95	80	40
4" x 50 metres	386	1.2	80	40
6" x 10 metres	176	.5	200	100
6" x 20 metres	353	1.0	200	100
6" x 30 metres	529	1.5	200	100
6" x 40 metres	706	2.0	200	100
6" x 50 metres	882	2.6	200	100

Water Circulation Pits (Mud Pits)

These must be sized correctly for the size of hole being drilled to ensure the minimum fluid contamination and to prevent drilling crisis developing with losing circulation with insufficient make-up water available.

Broadly theory states that the surface mud pit must be 3 times the anticipated volume of the completed hole and consist of at least a separate settling pit (2 times hole volume) and a connected suction pit (1 times hole volume) . See illustration of classic pit design - this can be modified with the Port-A-Rig by tilting the circulation tank towards a single suction pit that should be 2-3 times the volume of the hole - with use of two interconnected dug pits if very fine sand formations are anticipated and greater settling time required.



TYPICAL MUD PIT LAYOUT

Bearing in mind the need to obtain the crucial up-hole velocity rate enough to lift but not erode the hole it would be useful to introduce a weir or flume to measure the flow of the returning circulation - adjusting pump valve or throttle setting to maintain a constant flow (see RIG MODIFICATIONS)

In practice on some sites make-up water can be hard to locate in sufficient quantities to meet above criteria. If this is the case the following advice should be followed:

1. Use a light drill fluid additive or even natural clay to prevent losses into the formation.

2. When entering the aquifer change the fluid to prevent infiltrating the aquifer with contaminated fluid.

Use of down the hole hammer

Generally if ground cannot be drilled with a dragblade drill bit it is hard enough to be hammered - the exception (as expirenced around Battambang once) to this is when faced with a matrix of hard rock boulders loosely surrounded by small stones and soil. This type of ground is notoriously difficult to rotary drill and should not be attempted with the Port-A-Rig or indeed the PAT. It is impossible to drill with a dragblade with either water or foam as the dragblade will not penetrate the hard boulders - using the hammer will allow the boulders to be smashed but the high velocity compressed air will blow the light matrix of material from around the larger stone creating a void that will be difficult to lift further material past - worse that broken lumps of boulder are liable to fall in behind the drill bit and trap it calling for nice powerful hydraulics to pull the bit back through.

There are 3 - 4 alternatives to this situation

1. Dig a shaft onto firm rock - this can be ringed in the hope any water discovered will be sub artesian and flow upwards for removal by bucket and rope. The Port-A-Rig would then be set up on top of these rings with a temporary 4" casing being inserted to well base to allow full removal of cuttings. If drilling succeeded and water did percolate upwards it would be possible to drill further holes in the same well - possibly angling them slightly outwards to stimulate more flow into the well. If water is not sub-artesian a hand pump will have to be fitted into the 90mm bore - Again shaft on rock head left open to allow supplementary or replacement wells to be drilled later.

2. Use Dando Percussion rig to drive steel casing onto rock head set 4" permanent casing and cement in place. Remove steel casing and then use Port-A-Rig to hammer into the rock

3. Avoid sites overlain with this matrix of boulders keeping to sites that are just weathered outcrops of rock.

For compressed air drilling to work at all it is essential to use a compressor large enough to be able to clear drill cuttings from the bottom of the hole up the annulus between borehole walls and drillpipe. The minimum velocity is judged to be about 1000 metres/minute with an optimum requirement of twice that. millimetres are quite critical drill bit diameter wants to match the surface casing as closely as possible to provide good hole cleaning.

Oxfam Cambodia have 175CFM (82lit/sec) compressors when used with the 62mm OD port-a-Rig drillpipe and 90mm button bit there is just over the minimum up hole velocity of 1000 metres/minute. 4" casing available in Cambodia however measures 103mm bore German or Thai origin or Vietnamese 107mm bore - both these bores are a little too big for use with a 90mm drill bit.

90mm bit diameter might also be too tight for any hand pump installation so it would be better to drill 95 or 100mm diameter. Although just satisfactory with 175CFM a larger 250CFM compressor would be more comfortable. Care should be taken to connect compressor with short large diameter, but safe hose, to minimise pressure/flow losses.

To contemplate holes drilled "low tech" deeper than 50-80 metres will be difficult without going relatively hi-tech with positive displacement mud pumps and mechanical assistance with drillpipe hoist.

WELL DEVELOPMENT & DESIGN:

Why use a gravel pack? To create a filter that will hold back fine material that would otherwise enter the well screen and maximise the well yield is the answer.

With the use of uPVC screen system it is easily possible to obtain screens with good volume of open area with extremely fine slots that negate the need of requiring to artificially place coarse material to prevent fines from the aquifer entering the well screen.

For a gravel pack to work it needs to be evenly placed at a thickness of 2" around the screen. Holes drilled with light rigs are most certainly not straight, neither is the plastic pipe and rarely are centralisers used to ensure the screen is in the middle of the hole

Any hole drilled with water or drilling fluid will absorb circulating water into its permeable layers taking into the formation all manner of fine material and creating a curtain of fines several inches thick that will have to be removed if the well is to produce effectively. The process of removing these fines is greatly hampered by shielding this curtain of wall cake with a layer of gravel pack.

The following simple method of natural development is recommended - particulary when looking for small volumes of water from thin layers of sand.

1. Drill to depth being most particular in logging the formation drilled and keeping marked depth samples of sand layers. (Good practice for Hydrology to retain these samples)

2. Decide on well screen placement - coarser the sand - thicker the bed - above impermeable layers have always got to the favourite places. If you have a choice of screen slot size take a "wet finger lick" of physical sample of sand aquifer and rub it against the slot - judge the screen perfect if it lets some through and other bits bridge - but for a hand pump water supply sand that mostly bridges is OK (a magnifying glass can help with fine sand & screen).

3. Assemble casing and screen string in hole.

4. Pump clean water down centre of casing and allow water through screen and to rise upwards displacing all the drillfluid/circulating water from the hole and away to waste. Usually just holding a pump delivery hose inserted in the top of the casing with a cloth wrapped around makes a sufficient seal to force the clean water down the casing and through the screen allowing it to displace the dirty drill fluid up the annulus between casing and borehole to the surface.

5. Begin development of the hole - ideally a surge block to gently surge water out into formation on the downstroke and pull water into the well from the formation on the upstroke - this action pulls the fines into the well and

gently sorts a natural filter bed around the screen. A compressor can be used to airlift a column upwards and then air turned off to allow the water to drop downwards and out into the formation - creating a similar in and out surging action

Good development takes patience and time (A "rule of thumb" that good development takes at least as many hours as the drilling) - a very productive coarse sand aquifer needs little work to produce clean water - a fine sand aquifer may appear to yield nothing until several hours of development are complete.

In soft formations the surging action will collapse the aquifer onto the screen loosening up the layer of wallcake - in lightly cemented formations and uneven layered material only partial collapse might occur - but in each case the water bearing part of the formation is being cleaned of drillfluid contamination and fines and allowing the available groundwater best access to the screen

6. Airlift the hole to remove fines periodically and repeat development until water is clean and developed

7. A gravel pack material may now be placed to "stabilize" the formation left open to a suitable depth where a cement sanitary seal can be placed - ideally at a depth of an impermeable layer. Cement grout should consist of 27 litres of water mixed with 50Kg of cement to yield 33 litres of grout

RIG MODIFICATIONS:

Based on experience in Cambodia the following modifications will be incorporated into future production Port-A-Rigs.

1. Increased ratio on hoist chain - probably about 8:1 - probably look at doing this with an identical wormbox model as used on rotation for spares commonality. Probably also incorporate a torque limiter just as a final protection for the over boisterous operator.

2. The mud tank is the standard mounting for any type of drilling it works well with air and water - by tilting it towards a dug pit acts as a first rate settling pit - but would be improved if we had a round exit spout so return flow of circulating water could be accurately measured with a bucket or simple gauge - deep holes with just water no mud additives up-hole flow critical to drilling performance.

As the mud tank is always used the multi-purpose scaffold can be dispensed with. Pivot points with location pins can locate front of the rig skid and the rear levelled with a sliding leg and screw arrangement. Rig can then be more simply rigged and will always be central to 8" hole in floor of tank.

A small instrument level bubble fitted to base frame would ensure mast verticality

3. The cheeks that support top chain sheave have been worn by the chain and require more clearance - also tensioning needs very secure locknuts as I think chain tensioning is vibrating off with use.

4. Mast lock screw will be offset from mast pole incorporating a swivel plate to clamp mast - this will give chain complete clearance when heavily loaded and do away with the need to having a loose screw as pivot plate will be captive

5. Make engine switch more accessible to operator

SHOPPING LIST - USEFUL ITEMS

The overall drilling programme would be enhanced by the procurement of the following items:

1. Polymer Drill Fluid Additive. Should need 10-20kg per hole depending on volume of mud pit used.

Rather than buying proprietry "drill polymer" effort should be made to track down a source of "Guar Gum" E412 - Food grade 100 or 200 mesh. Bangkok must be a source and cost should be considerably less than branded drill mud - check a sample - does it build viscosity of 40 Marsh funnel seconds in 30 minutes at approx .3% mix

2. Marsh Funnel & Jugs - to measure viscosity of mixed fluid

3. Water level Dip tapes. Saw one in Battambang but it was always on the wrong rig at the wrong place - every rig and development/pump insertion crew should have one always

4. The Port-A-Rig would be capable of reaching greater depths if it had a larger centrifugal pump - possibly capable of being used in series with the 2" Trash pump. Horsepower wants to be 12HP plus and pump capable of high head generation, if possible, in preference to high flow.

5. Surge blocks for well development - together with a simple frame & lever to maintain a regime of 400 - 600mm surge strokes over a period of hours. After discussion in Phnom Penh Eureka offer to make up a standard surge block kit for use on casing 50mm through to 107mm. Surge block for use either on pump rods or on a wireline with a weight hung below

6. Set of sand sieves

7. A heavy duty strap wrench to help turn tight drillpipe

8. A collection of 1.1/2", 2" & 3" Camlock hose couplings for use on PAT and Port-a-Rig setups.

MONITORING AND FOLLOW UP MISSION

It is reccomended to leave formal monitoring of the ongoing rig performance to "market forces" If it a useful machine it will be used by Hydrolgy and hopefully be in demand. It would be nice to work a pair of Port -a- Rigs - particularly a machine with all modifications in place.

Improvement and fine tuning a drilling operation is a constant programme and the programme in Cambodia would benefit from further visits to strengthen techniques and provide "on the job" training

PDB 19 June 1992

DIARY OF VISIT TO CAMBODIA

PETER BALL - EUREKA UK LTD

MAY 25th - JUNE 21st. 1991

MONDAY 25th June:

Arrive Phnom Penh about 11.30am - met by Jeremy Ockelford - taken to Mittacheap Hotel - visit Oxfam office - sit in on meeting with UNHCR coordinator for water engineering.

TUESDAY 26th June:

Visit department of Hydrology and unpack boxes of the Port-A-Rig - all boxes as shipped and sealed. Re-assemble the rotary head on mast and erect machine - becomes obvious Khmer staff familiar with drilling equipment in general and mechanically adept - many willing hands and minds work out quickly what's what.

In the P.M meet with Waldmer - Unicef drilling engineer. Enter a very frank and direct discussion on drilling procedures in Cambodia - he demonstrates a very sound knowledge of drilling techniques and experience in overcoming specific problems encountered. Of most interest he speaks of low water producing sand aquifers that are drilled without bentonite or any other fluid to prevent formation damage - always drills with water allowing it to naturally build viscosity in the clay and then replacing the recirculating fluid with fresh when entering the sand layers.

Speaks of cases of high losses into formations and collapsing holes in fine sand in certain areas.

He is sceptical about us operating our 3" hammer at 175 CFM airflow effectively. Remains very keen to evaluate the rig in the field.

Late PM re-visit Hydrology department to plan the drilling of the 1st hole on their grounds. provide a shopping list of some ancillary tools - Jerry can,engine oil,petrol,funnels, tie down rope, shovel etc.

WEDNESDAY 27th May:

Heavily overslept with jet lag and arrive at Hydrology department barely in this world. Begin to set rig up and encounter first major hold up - to operate with the mud tank we require a short 1 metre length of 6" bore casing to bury in the ground. Hydrology have not one piece - the "market" produces - German made (as UNICEF supplies!) 165mm casing but the 5.7/8 bit is just too big to fit. We cut a steel 6" piece from hydrology stock which the drill bit just squeezes through with a clearance of .000" of an inch - we have to fuss around lining drill mast

up exactly to inch the bit through the tight casing. Hydrology crew advise a sand bed at 6-7m so we drill to just 5m allowing a proper run in the morning 07.00am start.

Note that Hydrology department have virtually nil back-up resources ie shovels, buckets, hand tools lot of the day lost just getting hold of such stuff.

Rig has mechanically performed well save for an oil logged air filter blocking air intake - engine must have flown or be stored on its side somewhere.

Khmer Headquarters crew and representatives from Prey Veng & Svay Rieng crew quick on the uptake of initial rig operation.

In our search for 6" casing with clearance Waldemer shows us PAT drag blades of 5.1/2" diameter bits look of good quality with tungsten edges - would make a lot of sense to make a sub-adaptor to use PAT bits on the Port-a-rig.

THURSDAY 28th May:

Start drilling 07.00am in relative cool - almost immediately circulating fluid breaks around sealed in 6" pipe and washes around base of tank - most cuttings still being cleared. As we have abundant drilling water from nearby pond we press on pumping water direct from pond into drill head. Drilling progress is steady - ground is mostly lightly cemented - predominantly sand with the cementing clay being washed by the drilling water. Reached 21 metres at about 10.30am but a problem with water circulation being cut off - flow is very low and hard to access when running out around casing and eventually flow blocks altogether. Suspect drill bit might be partially blocked and decide to remove string - pipes are not tight so it is unlikely formation has caved in. Bit is very partially blocked with sticky clay and I contemplate that the pump might well be struggling to deliver the required flow to clean the hole - we are operating with 8 metres suction hose with a suction lift of 2 metres - the drill bit does not have very large through holes possibly creating pressure loss all perhaps adding up to a grand total of poor up-hole velocity. Ask Hydrology to open holes up on drill bit and borrow a PAT 5.1/2" bit and drillpipe from UNICEF.

In the afternoon we rig down machine contemplating drilling another hole as the 6" steel casing has slid down the hole from view - having moved rig tank we recover steel casing and decide to insert 3 metre plastic casing and continue.

Rig is left set up ready to re-enter the hole in the morning. A search is made to find some hose fittings to allow us to pump water from the pond into the tank and have just the short hose as suction from the tank to the pump - I am hoping reduced suction head, shorter suction hose and bigger drill bit through hole will enable us reach the target of 30 metres. I

might have to add some polymer to build viscosity to help clean the hole if problems persist tomorrow.

FRIDAY 29th May

Re-enter hole with tank circulating water down to 18 metres - no problem after 18 metre water flow drops off very quickly. Mix some Guar Gum 2kg into tank - builds viscosity very quickly and removes clay particles from suspension in tank. - commence circulation and produce an enormous return of material from bottom of the hole. I am quite certain hole was not cleaning properly with just the water flow and the 5hp 2" pump. We drill on to about 6 metres but drillpipe becoming very tight - circulation dropping off and an enormous pile of material at surface - very likely our mucking about has caused a substantial cave in - but ground has been relatively hard - suspect some sort of sub-artesian water flow causing collapse or maybe just the hole being enlarged by erosion of circulating fluid.

Decide to abandon this hole having learnt enough! Crew remove pipes methodically and pack up machine - taking care to wash it all down - most impressed!

I am becoming concerned that the drilling conditions in Cambodia are variable and we will need to be careful to work on suitable drilling objectives for the machine in what is becoming a very short trip. (Note to Jeremy 29 May 1992).

Visit a potential hammer site 30km from Phnom Penh. Used by UNICEF as test drill site. Plan to mobilise kit and drill tomorrow.

Discuss with Jeremy & Sakhon (Hydrology) material requirements for Battambang and the need to load materials and equipment on Sunday to avoid crowding too much into Saturday.

Jeremy tells me extra drillpipe will arrive Wednesday next week with hope it might be cleared for the following Monday.

SATURDAY 30th May

Load up rig onto Hydrology Pick-up truck and tow Hydrology compressor out to chosen site. crew set up rig with little fuss - mix polymer for stable foam drilling (36 sec viscosity x 1% foam addition using the hand pressure pump.

Begin to discover compressor is not in the best of condition - great problems observed in trying to start engine and keep it running. Stable foam drill through top hard clay layer with 5.7/8 dragblade - works like a dream lifts out all the cutting very nicely.

Case the hole with 4" Vietnamese pvc and insert hammer and start drilling with water and 1% foam addition being injected. Hammer works steadily but cuttings not been evenly removed -

suspect insufficient air volume. Drill into hard rock at a rate of about 1metre every 8 minutes - stop at 4.5metres as crew very worried about state of the compressor it is blowing a considerable amount of oil and we have no compressor oil to replenish - I am concerned we have insufficient volume and would have to rely heavily on the water injection to help keep the hole clean.

Yohannes suggests the Central Hydrology chief driller, Chok Chen who has shown proprietorial rights over the equipment and has beavered away throughout the drilling should travel with me - this is a good idea as he will get the full experience to be of most use to draw on after I depart - he will also complement the very shy or ineffective interpreter (my fault I haven't discovered which to date) that Central Hydrology have provided.

Talk to Jeremy about materials and men we require in Battambang as well as the need to drill deeper in hammer test hole to discover water as evidently village is in need.

SUNDAY 31st May

Visit Hydrology yard to spend a largely frustrating 3 hours waiting for permission to be sought to break a padlock barring entrance to the store with the plastic casing. Visit is useful as some small rig things had been overlooked for loading.

MONDAY 1st June

Leave Phnom Penh and drive to Battambang - arrive 4.30pm - book into the Victory Hotel. Also bring Lieng - Yohannes interpreter from his project to help with communication

TUESDAY 2nd June

Go to Hydrology staff and get introduced to manager and discuss our programme. Truck gets unloaded and rig is loaded onto our pick-up ready for transport to site. I go to "government" mechanical workshop to get some heavy spanners to "break" (unthread) the DTH hammer and try to find bits to make up heavy duty clamp to hold hammer body whilst unthreading - having searched their large scrap heap and visited market hope we have come up with a solution - leave people nodding their heads and smiling thinking - I think - we are coming back Thursday hoping to collect finished items!

In afternoon travel 50km out to PAT drilling site - arrive just as they are pulling out of 27 metre hole having drilled through 9 metres clay - 6m sand - back into clay stopping when rig could not turn bit? As we watch circulation is blocked above bit - crew attempt to regain circulation continually topping up their 1 x 1 x .4 metres deep mud pit and trying to back ream drillbit - rotation stalls and crew regain rotation by rotating drillpipe with 24" pipe wrench on drillpipe - eventually they edge the bit upwards and regain circulation - then to their credit they start reaming back down the hole to clean out

blockage as we leave site.

My thoughts as I see operation is that it was tiny mud pit for such a hole and that no proper settling arrangement has been made. We visit next site - the one we will use the port-A-Rig on tomorrow with the PAT pump - I think? Also note drillpipe hoist on PAT requires less effort - more turns to lift pipe I counted 35 turns to lift 1.5 metres - will have to count the port-A-Rig but am sure ratio is lower. Centrifugal mud pumps are definitely limiting the depth of these small rigs - might try and experiment with boosting delivery head by putting two pumps in series - back to the market for more pipe fittings!

WEDNESDAY 3rd June

Arrive at site very nicely shaded under cover of tall trees. Set Up rig anticipating a 6" hole over 30 metres - get crew to dig a single 2.5 x 1.5 x .7 deep suction pit and arrange to slope rig mud tank so returns will "weir" over evenly. Seal in a 1 metre deep piece of 6" casing but this is washed around whilst drilling off 2nd drillpipe - dismantle rig and discover washout has occurred down extensive tree root system - set 3metres of casing - noting once more hole has erode open considerably larger than the drill bit. Drilling proceeds well but past 12metres 2" pump flow is slowing and there are signs of insufficient hole cleaning - PAT rig happens by so we borrow its 9HP 4" pump - flow is greater and we are rewarded with lumps of clay from bottom of hole take the hole on down to 27 metre through some coarse sand and back into clay. Crew decide to screen coarse sand between 22-24m and a very fine sand band 11-12m with 4" casing with .5mm slots. Casing run in and an initial airlift removes water from hole before the gravel pack is placed. Airlift then demonstrates water has been located sufficient for hand pump - a lot of fine sand blown clear and will need much more cleaning before all fines removed.

When approaching 28metres it is apparent it is very hard to turn hoist handle - I have established there is a 3 times ratio difference between the PAT and Port-A-Rig - it is the struggle to hoist that is holding us back we still are rotating the drillpipe happily - I do not like the pump flow - even with the larger PAT pump and think we must try a polymer drill fluid additive. Resolve to attempt to make a 3 / 4 : 1 chain reduction on the hoist to be able to take the rig deeper.

Also imagine or note a goal for the Cambodians to finish the allotted task within a working day - it seems it must be finished working up to a frenetic work pace at the days end with any short cut being seen as an advantage.

THURSDAY 4th June

Before looking for bits top modify rig hoist ratio we decide to undertake a simple 12-15metre DTH hammer hole out at a large "internally displaced" settlement camp. We decide to probe a 4" drag blade hole to determine depth to rock - first drillpipe goes

in straight and true and is very clean with some help with some foam - next pipe down we immediately hit something very hard - we remove drillbit and replace with the hammer - hammer bangs a bit then enters soft bitty ground so we decide to replace with the dragblade once more ream out hole from 90mm hammer bit to 98mm dragblade and attempt to drill on very very hard but we do grind away about 250mm - decide to ream out with the 6" bit and set casing as deep as we can ream - despite remaining a very clean hole we raise pipe about 600mm and come against a very firm blockage preventing any further hoisting. We try every bodies favourite ideas from buckets of water to water circulation - ground is very permeable all flow disappears eventually resort to attempting to jack the pipe but it is still against something very solid - disassemble the machine around the drillpipe and plan to dig down to retrieve drill bit.

My thoughts are we might have drilled around a hard laterite boulder that has rolled into the hole jamming the drillbit - or possibly a 10" length of uPVC pipe that disappeared from view when we where hammering - but the drillbit although very free below the blockage - very much goes "clang" when we now lift the stuck pipe by hand. What a very frustrating day - We decide to go-ahead and modify the hoist ratio whilst errant pipe is being removed with plans to drill at the site again to get on top of this rock drilling. Plan to radio Jeremy to suggest we continue in Battambang area - possibly bringing remaining drill crew here for training - we need to hit some consistent drilling to allow crews to benefit and to begin to reach conclusions on the port-A-rigs ability

Khmer crew have demonstrated to me they are "grafters" and well able to problem solve themselves with good commonsense - the sound basis for very capable drillers

FRIDAY 5th June

Enter the "market" to search out some sprockets chain and bearings suitable to change hoist ratio - settle for a motorbike drive(13 tooth), driven sprocket (41 tooth), chain and a pair of bearings. Search out a back street engineering shop with a bit of a plan in my head. Kymer engineer, a perfectionist, is not to keen on my realist solutions looking at his machine tool capabilities and wishing to get operational as quickly as possible! - we reach - I think - an engineering compromise with promise that the job will be complete by Monday morning.

Arrange to visit him on Sunday to see how is getting on and possibly renegotiate some items!

Travel out to our site of yesterday to discover drillpipe dug out - the digger of 3metre deep hole ($10.00 fee) reports pipe stuck behind a horrible boulder - spoil pile shows we had entered a matrix of soft laterite with rounded boulders the size of rugby balls. This is awful drilling a hammer is needed to bust the boulders but the air blows the loose matrix away leaving the now broken and loose rounded boulders to fall in and jam

drillpipe. To drill this you need machine overkill and a bit of luck -

1. To drill down quickly with large 6-8" hammer bit with plenty of air and foam and hope matrix just about holds together before to get surface casing in.

2. Simultaneous casing devices were made for this type of ground .

Back to "low tech" we have the following additional choices

3. Dando shell & Auger to drive 6" casing and set and cement 4" upvc onto rock then hammer with rotary.

4. A dug well ringed down onto the rock - temporary 4" casing set and hope any water will be sub artesian into well base - or set hand pump below in 90mm dia hole

5. Find the rock without the boulders on top!

Visit workshop making hammer stripping spanners that have now received 36 hours engineering manhours (£500 worth in UK!) to create almost a set of spanners - a few more hours required to get the fit right!

SATURDAY 6th June

A quiet day Hydrology Department having "political meeting". Collect the hammer stripping spanners ($20.00!). Check on progress on hoist modification but not much done yet as the engineering shop just finishing extensive tractor repair job.

SUNDAY 7th June

Check progress of hoist modification and am pleasantly surprised to find large sprocket already mounted and work progressing well with bearings and mounting for the small sprocket

MONDAY 8th June

Hoist modification finished a very good job considering materials and tools available - cheerfully pay the $17 charge for machining 7 components - best value engineering I have ever spent money on. Transport rig to a village planning a deep 4" hole. Setting up goes well - fill mud tank and pits from a bowser - drill 6" down first pipe - 2.5metres and slip in a piece of 4" casing as conductor tube. Drilling at 4" starts well bags of pump flow and hole cleans well - at 11.5metres depth apparently in clay we begin to lose circulation into the formation - we mix polymer and cut losses back a bit but still losing - mix more polymer and add 20Kg rice husks and regain sufficient flow to drill on another 3 metres but still constantly losing water - my original 10kg sack of polymer almost all used up.

We remove pipe and pack up rig with plans to continue tomorrow - I think - if we can pump water direct from a lake a few hundred metres away. Loss of circulation quite remarkable all returns indicate predominantly sticky clay! if it's that permeable is there water in it? local opinion says not!

The new hoist ratio has brought smiles all round.

TUESDAY 9th June

Continue with hole reaming out as we approach bottom - no great lost circulation could well have been a partial blockage giving us all the problems of yesterday - drill in with 33metres of PAT pipe planning to go as deep as possible - couple both PAT pump and 2" pump in series to increase pressure - drill onto 45metres (World Record!) and then we get a problem with the pulldown chain - with load on the mast the mast bends slightly and chain stretches giving enough slack to catch to snag up on a welded spreader tube inside the mast - a reductant item but in the way. We will have to have a look in the morning and perhaps visit a friendly workshop. Very concerned with pump flow at 45metres we are drilling very fine silt so not difficult to lift but we will have trouble handling clay or coarse sand.

I have now half a dozen clear modifications to incorporate in next to make it easier to rig and use machine - nothing like field trials overseas!

WEDNESDAY 10th June

Sort out mast cutting out offending tube and take the opportunity to reinforce the top sheave bracket which has some chain wear.

Strip the hammer down to show in pieces, actually Kymer crew strip hammer whilst I am out trying to buy a spanner - but anyway show them it various bits and point out the bits that clog with muck and cause the hammer not to work - also change oil on the engines.

Come across a local well digger who has just copied a PAT rig out of bits and pieces of scrap machinery - it has cost him about $2000 - with PAT drillpipe made in Battambong for $7.00 each 1.5m length. An extremely resourceful bit of engineering.

Review our drilling performance of yesterday calculate the pressure loss through the PAT 32mm bore drillpipe trying to push 80 gallons/minute through - tables show loss of 51 feet per 100feet - Typical Centrifugal pump limit of around 85 feet - no wonder we are not achieving sufficient up-hole flow to clean the hole.

Rig transported to site 1.1/2 hours away - planning a 30 metre hole and a programme of natural well development tomorrow

THURSDAY 11th June

Rain beginning to effect operations - truck bogged on way to nominated drill site. Alternative site picked and set-up commences - delays in trailering water to site from a river 1km distance. Drill a 6" hole insert 4" casing to 2.5metres - 4" hole then drilled down to 24 metres - with 2" pump only - passing through a sand layer at 7metres and back into clay. Leave site as rain comes in and site is a long drive to Battambang. Wait and see to see what was finally achieved by drill crew left on site. (Rig completes hole to 30metres, inserts 1.1/2 screen at 27-30m - develops with air compressor very clean clear water supply)

FRIDAY 12th June

Drill 4" hole to 24metres + 2" pump with sand encountered 13-17m - screen off with 1.1/2 Screen and develop - not long enough to clear supply.

SATURDAY 13th June

Drill 6" hole to 28.5 metres require both 2" & PAT pump to provide circulation. Layers of sand from about 9m through to 26 metre some very coarse. Discuss with crew "natural development" don't believe I have many converts - lots of back chat going on and sideways glances - anyway they follow my guidance but regretfully hole very short of water - try developing with suction pump but rest water level lower than 8metres - airlift takes over but very little water.

Khmer drill crew settling in with the rig very well now that we have done 3 production holes one after the other.

SUNDAY 14th June

Rest & Relaxation

MONDAY 15th June

Plan a rock hole - set rig up and slow foam with 6" bit down to 6 metres hand foam pump working well could do with a touch more flow - larger piston - less pressure. Khmers (as with all uninitiated drillers) treat foam drilling with suspicion and they keep opening air valve when I am not looking - I think they are getting the idea towards the end. Run out of drill fluid additive so have to turn over to water - down to 12 metres where drilling quite hard - case off with 4" and cement tail for a good start in the morning - clear water from hole and note we have actually got a small supply of ground water.

First real rig component problem an oil leak from the wormbox that will need investigation tomorrow.

TUESDAY 16th June

Sort out rig investigating oil seal leak - actually insignificant with oil level in wormbox still high. Crew see drive belt assembly stripped out.

Drill on with hammer - hole has water level resting at 5metres this is blown clear and hole dry - cement has worked perfectly. Drill into a cemented matrix of rock hole becomes very sticky - we are injecting water experimenting with local washing powder - water injection rate wants to be higher to clean the hole properly. At about 14metres begin to go through an uneven layer and we are rewarded with hole immediately becoming wetter but still sticky as we drill on drilling speed increases as hole cleaning with water - drill down to 19metres a couple of metres into hard grey consolidated rock. Clean hole before inserting 1.1/2 screen. Whilst drilling this matrix of cemented formation OK odd chips of stone would jam behind the hammer requiring patience of reaming up and down with air circulating and drillpipe turning until blockage cleared.

The rig can use a hammer but care must be taken to keep the hole very clean to avoid trapping the hammer rotation and hoist power is extremely limited. I am very pleased the cementing in of surface casing has given us a clean start into rock hard enough to remain stable with hammering and airflush

Hole is cased and water level measured at 4.5 metres - well developed with the suction pump and within 10 minutes is producing clear water at about 1500 litres/hour. Crew finish installation of Cambodian made hand pump.

WEDNESDAY 17th June

Travel to Sissophon to visit Bantey Meanchey Hydrology. See both Dandos at work one trying to rehabilitate brick filled 6" steel cased well - but existing casing beginning to move downwards questioning original borehole construction.

Visit Hydrology yard and take details of a Dando casing hydraulic jack that requires a set of ram seals and repair seals for the hand operated hydraulic pump

PAT crew return from drilling a 50 metre deep 6" well - taken them 5 days - day 1 drill 26m - day 2 14m (to 40m depth) - day 3 5m (to 45m depth) - day 4 5m (to 50m depth) day 5 line and complete well. A borehole to stand testament to the drill crew perseverance and skill.

Whilst out of town Port-A-Rig has drilled a 42metre hole into clay - no sand found.

THURSDAY 18th June

Travel back to Phnom Penh

FRIDAY 19th June

Report writing Phnom Penh Oxfam office

SATURDAY 20th

SUNDAY 21st Travel Phnom Penh/UK Via Bangkok and a quick visit to the PAT factory arranged!!

19 June 1992

Depart Phnom Penh for UK