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UNITED NATIONS

UNITED NATIONS DEVELOPMENT PROGRAMME

BOREHOLE MAINTENANCE

MALAWI

Project findings and recommendations

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NOTES

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ABSTRACT

After the Government of Malawi identified the maintenance problem of 4,000 village boreholes, a request was made to the United Nations Capital Development Fund (UNDCF) for technical aid. This request was approved, and the project was launched in 1981. Its terms of reference were to: (1) rehabilitate deteriorating or defunct boreholes; (2) organise a better maintenance system; (3) train local personnel to carry out these functions; (4) supply equipment for rehabilitation and routine maintenance of pumps; and (5) supply equipment for three workshops to be constructed by the Government.

The project started in 1981 with the design of a simply maintained pump, and production started in 1982 under the mechanical supervisor. When the borehole maintenance advisor arrived in 1982, experimental rehabilitation work was carried out in Salima and the Lower Shire. The method devised proved successful, and two crews were specially trained for this work. From then on, the rehabilitation method was used in integrated ground water projects throughout the country. An electric winch system was experimented on and found successful in routine pump maintenance; and this system reduced the economic burden of maintenance to the central Government by half. All the equipment was delivered by the end of 1984, but only one workshop in Lilongwe was functioning.

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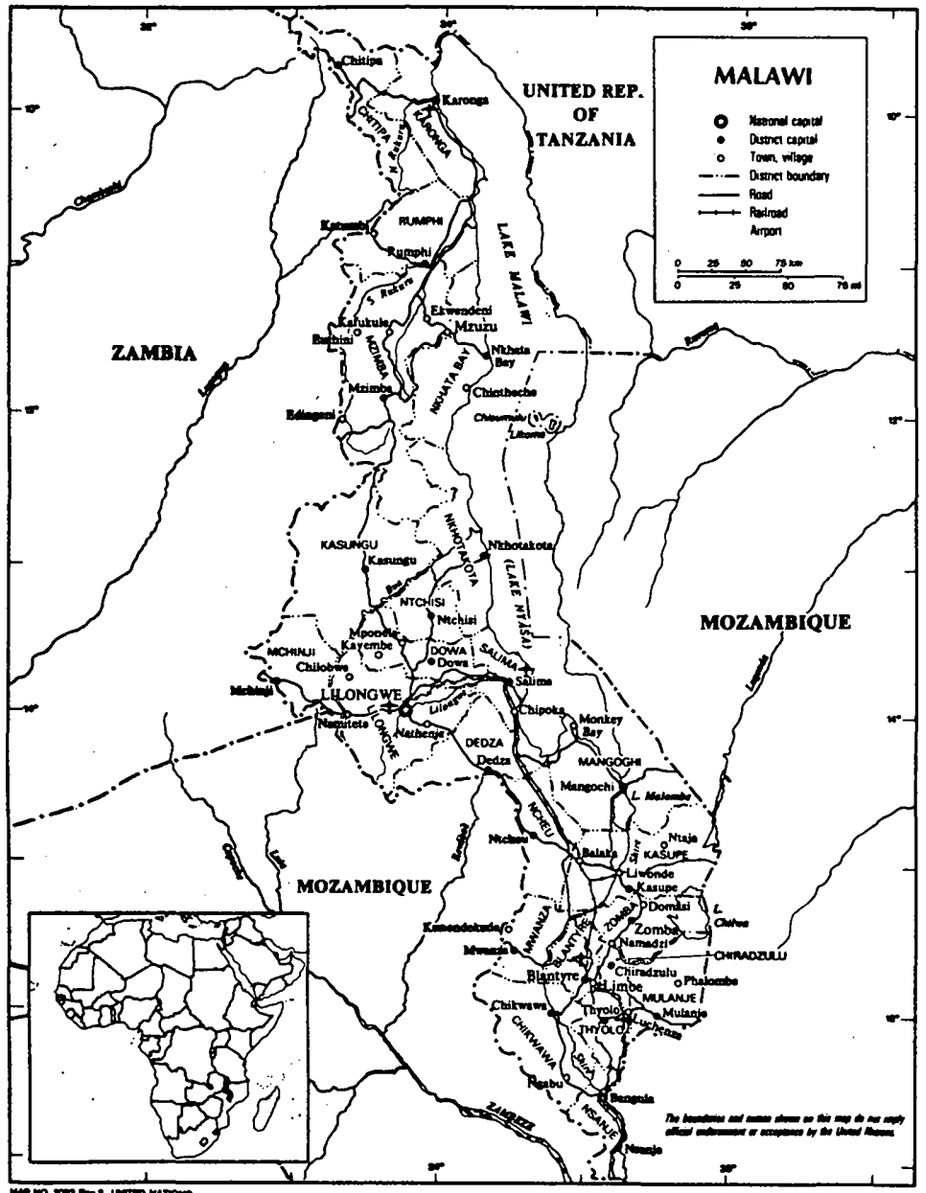
MALAWI
National capital
District capital
Town, village
District boundary
Road
Railroad
Airport
UNITED REP. OF TANZANIA
ZAMBIA
MOZAMBIQUE
MOZAMBIQUE
LAKE MALAWI
LAKE NYASA
Chitipa
Karonga
RUMPHI
Rumphi
Mzuzu
Nkhata Bay
Chintheche
KASUNGU
Kasungu
Nkhotakota
NTCHISI
Ntchisi
DOWA
Dowa
Salima
LILONGWE
Lilongwe
Chipoka
Monkey Bay
DEDZA
Dedza
MANGOCHI
Mangochi
L. Malombe
KASUPE
Kasupe
Domasi
L. Chilwa
Zomba
Namadzi
CHIRADZULU
Chiradzulu
Blantyre
Phalombe
MULANJE
Mulanje
THYOLO
Thyolo
Bangula
NSANJE
Nsanje
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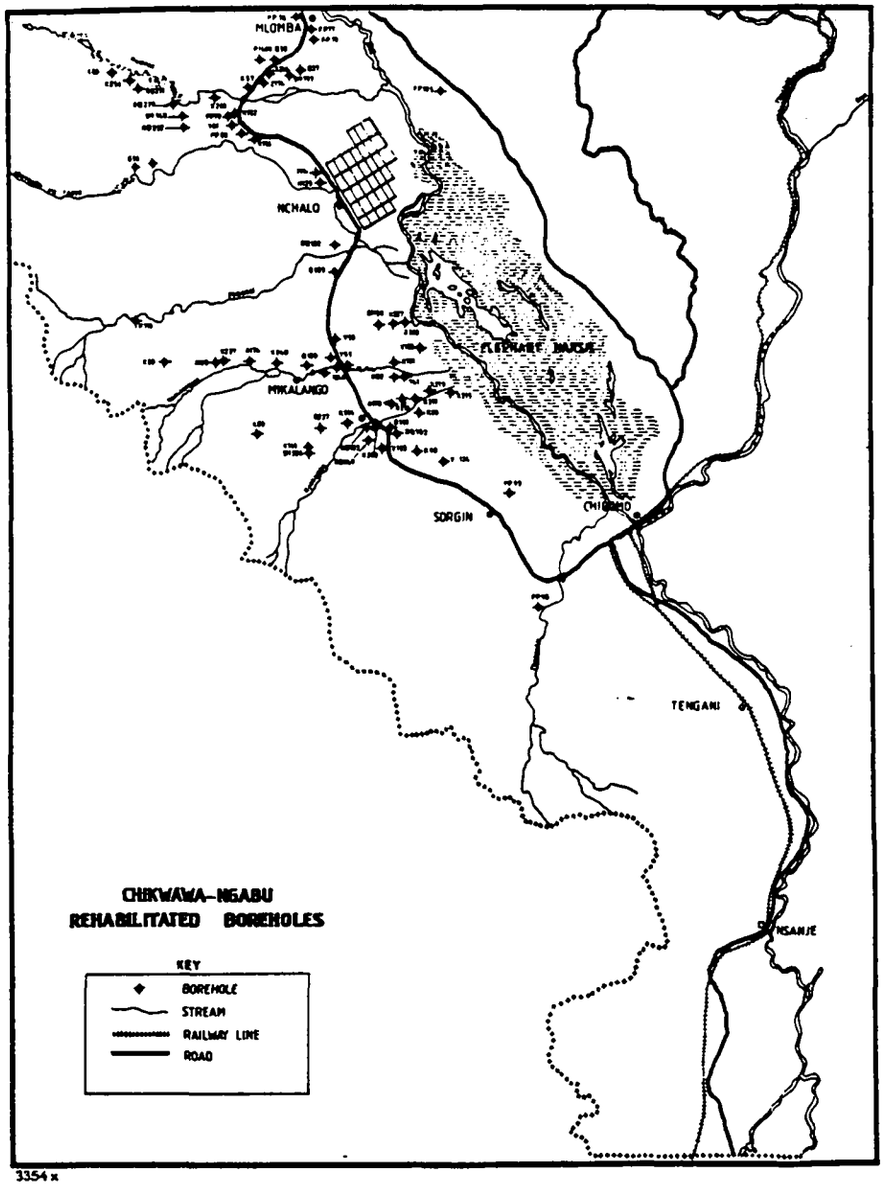
Map 2


MLOMBA
NCHALO
MKALANGO
SORGIN
CHIKWAWA
TENGANI
NSANJE
CHIKWAWA-NSABU
REHABILITATED BOREHOLES
KEY
BOREHOLE
STREAM
RAILWAY LINE
ROAD
3354 x

INTRODUCTION

Boreholes, as a nucleus of rural water supply, were introduced and developed in the early 1930's. However, between 1930 and 1960 only a few hundred were developed. From the 1960's the Government of Malawi gave priority to the development of rural water supplies in its development strategy. The Government realised that in an agricultural-based economy such as Malawi, 90 per cent of the population who lived in the rural areas required a clean and safe water supply for its socio-economic development. Therefore, by the early 1970's the borehole population had grown to thousands, and by 1979 there were 4,000 boreholes. There are now slightly over 5,000 boreholes; however, this accelerated development brought with it two major problems. First, the technology of construction and development of boreholes had to be standardised regardless of the geology and hydrogeology of the area. Second, the administrative and personnel training did not develop at the same rate as the development of boreholes.

The standard way of construction of boreholes involved drilling an eight-inch hole, 30 to 55 m deep and lined with six-inch mild steel casing. About 20 per cent of the steel casing was hand-slotted with either hacksaws or torches. Crushed construction stones, from 1/4 inch to 3/4 inch (aggregate), were used as gravel pack in the annular space between the eight-inch hole and the six-inch steel casing. This was done at an average cost of 5,000 Kwacha ($US 1 = K1.50).

The open area in the steel casing was less than 5 per cent and the gravel pack could not screen out sand and silt from entering into the borehole. The silt in the borehole was drawn into the cylinder and the cup leathers were scoured due to the abrasive nature of the sand and silt. This then required a higher rate of replacement of the cup leathers than would otherwise be necessary. Each replacement visit was done with a five-ton truck that had a manual one-and-a-half-ton winch mounted at the back. The more the borehole silted the more visits were required to repair the malfunctioning pump or replace a broken part in the pump head.

With time, more and more boreholes, especially the old ones, were silting to the point where it was unprofitable to maintain them. They had to be closed down. Indeed the problem was so bad that the 20 maintenance units could hardly do routine services of the boreholes, but could respond only to completely broken down boreholes.

As new boreholes were developed, a percentage of the old ones were closed down. By the time the Tejpal report came, 50 per cent of them needed desilting, 30 per cent of the pumps needed immediate repairs and 250 boreholes had already been shut down due to silting.

It was in the light of this problem that the Government of Malawi requested assistance from the United Nations Capital Development Fund (UNCDF) to solve this maintenance problem. The consultant, Mr. N.U. Tejpal, recommended a large-scale desilting and rehabilitation programme in 1979, as well as strengthening and improving pump maintenance operations. He further recommended that the rehabilitation programme and the pump maintenance operation be assisted by one drilling

advisor and one mechanical supervisor respectively. The grant agreement between the Malawi Government and UNCDF (Project No. MLW/79/L08; Maintenance of Boreholes) was approved by UNCDF in October 1980. CDF inputs (valued at U$ 1.138.000, see Annex 1), were for drilling equipment, vehicles, repair and maintenance of equipment and screens. The Government inputs were construction of workshops in Zomba, Lilongwe and Mzuzu at a cost of K60,000. The two experts were financed separately under a technical assistance project for three years (MLW/80/018 Borehole Maintenance). This was approved in January 1981 and its total value was US$ 380,900. The Senior Mechanical Supervisor joined the project in August 1981, and the Borehole Maintenance Advisor joined the project in January 1982.

I. BACKGROUND

A. Early assessment

Upon arrival in January 1982 the author spent three months observing and analysing the situation in the Government implementing agency, the Department of Lands Valuation and Water. Parallel to the preparation for the borehole rehabilitation project and with help from hydrogeologists from the British Overseas Development Administration (ODA), the Department was experimenting on a new borehole design that would increase the open area in the borehole screen, cut out the silting, and cut the cost down. Further, they were designing a new pump that would be easily maintained, even at a village level. The Mechanical Supervisor on the United Nations Project, having arrived in August 1981, was fully involved in the design of this pump and the setting up of a simple repair shop in Lilongwe for the maintenance vehicles and the Department's rigs. He also submitted a list of most of the equipment and tools required for the three maintenance bases.

The Tejpal Report had recommended that filters be put at the end of the cylinder so that the sand and silt would not enter the cylinder. This would cut down the wear of the cup leathers and so reduce the number of visits to the borehole. In principle, this reasoning was sound; however doubts remained as to whether this would stop the silting of the borehole. With or without filter the borehole would keep silting up, and would eventually have to be abandoned;

therefore the screen was installed as a temporary solution while efforts were made to correct an initially poor design.

A Dando 200 rig with a crew of six was borrowed from the Department since none of the project rigs had yet arrived. Four boreholes were selected in Salima in the lakeshore area. According to the records, the original depth of the boreholes was about 36 m, but many were found to be only 14 m deep.

B. Procedure

1. Desilting: The borehole was cleaned to its original depth using the Dando 200.
2. PVC inserted casing 110 mm, class 10, in 3 m lengths, 40 per cent of which was slotted and 60 per cent plain. The slots were 0.70 mm wide, which gives approximately a 10 per cent open area. The sockets connecting the 110 mm casing have centralizers to avoid vibration and to center the casing so that the annular space remains the same throughout.
3. Beach sand from Lake Malawi 0.75 mm - 2 mm was poured in the annular space as a gravel pack.
4. The borehole was developed by test pumping for at least four hours or until the water was clean.
5. The old pump was replaced.

For three and a half months these boreholes were monitored to see if they were silting but they were not. The Department was satisfied that a solution to borehole rehabilitation had possibly been found. However, the procedure required testing on a larger scale, and finance

became a problem since this mode of rehabilitation had not been envisaged at the inception of the project. The Department offered K89,000 to carry out a rehabilitation project in the Lower Shire which was one of the biggest problem areas. The programme would conclusively prove if this way of rehabilitation was effective, and it would also help the Government to find out the total cost of rehabilitation per borehole.

II. THE LOWER SHIRE PROGRAM

A. Setting up the program

The Lower Shire in Southern Malawi is an area in the African Rift Valley that is drained by the River Shire from Lake Malawi to the north. It is underlain with unconsolidated deposits, mainly of sand clay and silt with a few gravels. The geological layering shows complex interlayering between the gravels, sands, silts and clays. The standard borehole that had been designed by the Geological Survey Department did not take into account these geological conditions. As a result the Lower Shire was one of the areas most negatively affected by the design.

Because of its high agricultural potential the Government has put a great effort into the development of the Lower Shire. It has received a very high input of water development, almost more than any region except the Lilongwe area in the Central Region. There are over 1,000 boreholes in the Lower Shire alone, but due to the silting problem only 750 are functional; the rest are defunct. Of the 750 boreholes more than 60 per cent need immediate desilting, as they have silted to over 50 per cent of their original depth.

To test the rehabilitation procedure further, it was decided to rehabilitate 100 boreholes in the Lower Shire. The project was set up as follows:

1. Equipment used:
   a. One Ruston HR22 drilling rig (bought with project funds)
   b. One Dando 200 rig (borrowed from the Department)
   c. One compressor (borrowed from the Department)
   d. Two trucks (borrowed from the Department)

2. Personnel used:
   a. One counterpart supervisor
   b. Two drillers
   c. Four crew on Ruston rig
   d. Four crew on Dando 200
   e. Four crew on compressor
   f. Four builders
   g. Two drivers

The Government provided all running costs from the K89,000 earmarked for the project.

B. Project execution

An area of the highest density of silted boreholes was selected, and the whole camp was moved to a strategic location there. Usually the area had an average of 10 boreholes, which facilitated the camp being set up within 3 - 5 km of each borehole.

The boreholes were desilted, lined with PVC, gravel-packed and test-pumped. This was a one-day job per borehole per rig; the builders would come the next day to build the surrounds. This is an important aspect of rehabilitation which had not been envisaged at the inception

of the project, but was found to be necesary. The surrounds of a borehole are important since in most cases little attention was paid to the drainage of waste water. When this waste water stands around the borehole it forms stagnant pools of water which attract domestic animals to wallow and create a mud pool. This becomes a pollution hazard to the drinking water. The idea of the surround then was to build a good concrete plinth around the borehole, and supply a long outlet from the borehole, preferably 3 m from the pump. A brick drainage channel was built from the outlet another 4 to 5 m away from the borehole at the end of which was a proper stone-filled soakaway pit. This system was designed to work idealy with the Malawi pump (Afridev pump) since by design, the pump pedestal is buried into the concrete and should prevent water from spilling around the pumphead. Unfortunately, the project budget allowed only the fitting of 10 pumps and the building of 10 surrounds.

Of the 100 boreholes attempted, only 87 were successful. The reasons for failure in the other 13 boreholes were:

1. The original casing disintegrated, and the hole was caving too fast.
2. Pipes had dropped in the hole, and it was silting too fast for a fishing job.
3. The original casing had shifted so that the hole was now crooked.

Only in one case was a completely new hole drilled after failing to rehabilitate a defunct one. The compressor was only effective to a maximum of 30 m of sand. Its use was stopped.

C. Achievement of targets

The project in the Lower Shire proved beyond doubt that a method for rehabilitation of silted boreholes had been found. The average cost in Malawi for rehabilitation, complete with new surround was K1,500; K250 of this sum was for running costs. Two crews were trained for rehabilitation in the field, and are now highly proficient in this area. The major constraint became running costs, resulting in the Government's decision to use the rehabilitation unit in already-funded, integrated projects.

III. OTHER ACTIONS

The rehabilitation project in the Lower Shire was completed in October 1982. It was withdrawn because the funds earmarked for running costs had been exhausted, and also because the required target of the experiment were concluded. We returned to headquarters. At this point some of the equipment that had been ordered, specifically the vehicles, had arrived; however, the rigs had not. The store's construction and the Central Region workshop were complete, but waiting for the equipment.

In January 1983 the rehabilitation unit was given 35 boreholes to rehabilitate in an integrated project in Dowa West, which was funded by an international aid organisation. The procedure was the same as in the Lower Shire. When these were completed another 60 boreholes, funded by the Department, were rehabilitated in the Salima area to the east of Lilongwe in the rift valley. A new constraint was encountered where four-inch steel casing had been used, and it was impossible to line with 110 mm (4") PVC casing. We could not reduce the size since it would make insertion of the pump cylinder (3") into the three-inch PVC casing impossible. The best we could do was to desilt it and return the old pump, but the borehole would silt again within a short period. Another constraint was transported for carrying materials and moving rigs.

By May 1984 we had completed rehabilitation in Salima and moved to headquarters. Meanwhile, the rigs on the project had arrived and

and were already being used on rehabilitation. From July all rehabilitation units were working in Lilongwe North East where a new integrated project was beginning; this project will be completed in two years. Full attention was then focused on the maintenance system itself (see Annex 2).

IV. RESULTS AND RECOMMENDATIONS

A. Rehabilitation

Malawi has three distinct geological terrains in which boreholes have been drilled: (1) the rift valley zone with loose sediments; (2) the escarpment zone where bedrock is shallow; and (3) the plateau with a deep weathered zone. The old design of the 4,000 boreholes was only good enough for the escarpment and the plateau areas. Indeed, even in the plateau area the silting problem will become acute with time. The worst affected is the rift valley area; because of its agricultural potential the Government has devoted a large part of its resources in this region. There is the Karonga Development Project in the north with approximately 400 boreholes; there is the Salima Development Project with over 900 boreholes in the center; and there is the Lower Shire Valley Development Project with over 1,000 boreholes. All these areas are in unconsolidated deposits. Over 50 per cent of these boreholes have silted up and require immediate attention, but due to the financial constraint, the Government is unable to rehabilitate them all. The project's achievement was to supply the equipment and develop a method of rehabilitation for these boreholes; however, the bulk of restoration remains with the Government. The national total of boreholes needing rehabilitation is 2,500 of which 400 have been rehabilitated. The Government could reduce the recurrent cost of maintenance by almost half if the remaining boreholes were rehabilitated. As a result of this project, the Government

is now in a better position to carry out this work, either through our organisation or directly, if given the financial resources.

B. Regional maintenance bases

The workshop in Lilongwe was finished in June 1984. Due to delivery delays the equipment did not arrive until late 1984. Two courses were conducted in 1982 and 1984 for the mechanics who carry out maintenance in this workshop. This workshop is considered as the parent workshop and pesonnel will be detached from this one to workshops in the South and North. To date, only the one in the South is partly functional. It has been supplied with equipment from the project and soon, mechanics, welders, fitters and others will be sent to Zomba. The Government has yet to identify a building in the North which can be converted into a workshop.

C. Pump maintenance and repair

It will take some time to replace the existing pumps by the Malawi pump. As a result, mobile maintenance units will be required for some time to come. However, this has been improved by the introduction of the electric winch which has helped in the reduction of vehicle size, crew, and time required to lift and repair a pump. (This is described in Annex 2.) All vehicles have now been fitted with the winch and the crews are now fuly conversant with its operation. A training course for maintenance head operators was conducted by the section and funded by the project in March 1984, which is proving useful.

D. Evaluation and monitoring

In November 1984 an evaluation exercise was carried out on the boreholes that were rehabilitated in 1982 in the Lower Shire. The purpose of this evaluation was to determine:

1. If silting had stopped completely; if not, at what rate was it silting
2. How many times had the mobile workshop visited the rehabilitated borehole
3. Which parts had been replaced.

The results show (se Annex 3):

1. No silting was observed
2. The visits were down to one as compared to the original five or six
3. Few cup leathers were changed.

These results demonstrate conclusively that this method of borehole rehabilitation has the solution to Malawi's problem of silting boreholes.

E. Recommendations

There is a need to continue training personnel in borehole rehabilitation, motor vehicle maintenance, and pump maintenance on an annual or semiannual basis. The most probable constraint will be training facilities and trainers.

It is unanimously agreed that a rehabilitation method has been found during this project. What is now considered as a constraint is the cost of a rehabilitation programme to rejuvenate the 2,100 boreholes that

are silting . There is a great need to identify financial resources to continue their rehabilitation nationwide without loss of momentum.

Annex I

EQUIPMENT BOUGHT BY UNCDF

ITEM	ORDERED	RECEIVED
One drilling rig Ruston HR22		May 1982
Two drilling rigs, AXBE 250/6		Dec 1983
One Land Rover		April 1982
Eleven Bedford trucks (7 ton)		May - July 1982
Five Radio/telephone sets		April - June 1982
Drilling tools for AXBE rigs	Sept 1982	June 1984
One caravan (caravette 4)	Dec 1982	Jan 1983
Workshop tools (first order)	Oct 1982	Sept 1983
Workshop tools (second order)	May 1983	Jan 1984
Bedford Spares		Sept 1983
Twenty-four winches (electric)	April 1984	Sept 1084
Twenty-four sets of shear-legs for winches	Nov 1984	Jan 1985
PVC casing and screens bought locally on different occasions throught the project		
One Daihatsu 4x 4 (UNDP funds)		Dec 1981
One Yamaha 125 cc (UNDP funds)	Aug 1983	Sept 1983

Annex 2

THE MOTORISED WINCH SYSTEM FOR BOREHOLE MAINTENANCE

One of the terms of reference of the UNCDF Project was to find a way to cut down the heavy maintenance costs of boreholes. The system in use involves five-ton trucks with hand-operated winches mounted on the back. Each maintenance team is manned by six people. The hand operated winch is required to lift pumpheads from boreholes so that the down-hole components, i.e. cylinder, rising mains and rods, can be repaired. This system is slow and costly in terms of fuels and spares.

Small manual winches mounted on tripods were tested in the first year of the project. These were found to be slow, and the lifting potential was not adequate. More attention was then given to designing a pump head that could be easily maintained without the use of the winch system. The result was the Malawi pump which is still undergoing tests. However, even if it proves successful the country has 5,000 borehole pumps serving over 1.5 million people, and it would not be reasonable to discard the 5,000 pump heads in favour of the new pump. Therefore there is still a need to service the old pumps, so our attention reverted to the winch problem. In November 1983 we started experimenting with the "warn winch" which is manufactured in the United States but was locally available.

A. The warn winch system

The winch is powered by the car battery and is capable of pulling four tons of single wire. By original design it is mounted on the front

of the vehicle, and is supposed to help the vehicle pull itself out of mud when it gets stuck. Its high lifting capacity inspired the possibility of its use. If the winch could pull a four-ton truck, surely it could lift any pump head including the Double Wheel Climax pump which weighs close to a ton. However, the problem was to design a tripod for vertical lifting since the winch, as mounted, was only good for horizontal motion. One reason for having five-ton trucks was to counterbalance the weight of the manual winch; a smaller winch like the warn winch did not require a five-ton truck. Therefore, to experiment, we mounted the winch on a long-wheel-base Land-Rover and designed a tripod for the system for field trials.

B. Results of the trials

The winch was in the field for six months from October 1983 to April 1984. During that period it broke down only once because of a small fault on the switch which was repaired within a day. One other problem experienced was the length of the body of the Land-Rover, which was too short for the three-meter length of two-inch rising mains, and too small for tools and crew. The maintenance performance of the winch was superb. However, it was evident that a modification in the design of the head of the tripod was necessary. The problem was taken to Lilongwe Mechanical Development for correction and they designed a swivelling head with angled sleeves into which the tripod can easily be fitted and removed. The winch was then ready for further testing.

C. Conclusion

The "warn winch" has proved a successful substitute for the mechanical truck-mounted winch. Furthermore, it has eliminated the use of five-ton truck to long body one-and-a-half to two-ton trucks. This would automatically result in the saving of fuels and spare parts as well as the reduction of the maintenance crew from six to three. However, the most impressive result of this new electrical system is the saving of time. It now takes one hour to lift, service and replace the pump head instead of the original three to four hours required for the same job.

Annex 3

VISITED REHABILITATED LOWER SHIRE BOREHOLES

REHABILITATED BOREHOLE NO.	PART REPLACED DURING ONE REPAIR VISIT
E342	Pump hanger, grease.
RB132	3" cylinder, 2" rising main x 3
Q185	One litre oil (SAE 30)
K115	Centre Pivot
DM59	One litre oil (SAE 30)
Y58	One Pivot, grease, rising main x 2
A169	Two rising mains
X80	Hanger, centre pivot, and grease
X237	Half litre oil
X225	One rising main
A174	One x 5/8" pump rod
X226	2" Delivery pipe
M21	Rising main, gasket, grease
Q189	5/8" pump rod, half litre oil
X249	Pump handle
Y42	One rising main, half litre oil
SH271	One channel, one pump rod
Y57	One rising main, half litre oil
X219	Half litre oil, two bolts, grease
Q276	Half litre oil, two pump rods

REHABILITATED BOREHOLE NO.	PART REPLACED DURING ONE REPAIR VISIT
X218	Rising main, pump rod
X217	One rising main, half litre oil
X83	Half litre oil, 3" cup leather
A178	Rising main, one pump rod
HD103	Rising main, half litre oil
Q237	3" cup leather, half litre oil
RB272	5/8" pump rod, one spring
X208	One channel
Q191	3" foot valve
RB149	One rising main
RB102	One rising main, half litre oil
SM326	One pump rod, half litre oil
Y125	Goodwin pump-head, one litre oil
X256	3" cup leather, one rising main, half litre oil
A217	Pump cylinder, 7 x rising main, 7 pump rods
Q364	Grease
A213	Rising main, grease
PM98	½" nuts, one flywheel handle
X266	2½" cup leathers, half litre oil
SM153	Two con rods, two bearings, one gasket
Z174	2" socket, half litre oil
X258	Rising main, half litre oil
Y61	Rising main, 2 x ½" nuts
K156	Two rising mains, 1 x 5/8" pump rod

REHABILITATED BOREHOLE NO.	PART REPLACED DURING ONE REPAIR VISIT
Q421	One reducer
X204	Pump rod, grease
W203	Rising main, half litre oil
X202	Pump rod, one pint oil
X203	3" cylinder, four rising main
Q417	5/8" pump rod, half litre oil
W204	One channel, gallows
Q422	One 3" cylinbder, rising main
X72	Rising main, pump rod
Q419	Centre pivot, grease
Q362	3" cylinder, rising main, pump rod
Q300	3" cylinder, rising main, pump rod
X232	3" cylinder, rising main

Only 57 boreholes were visited, and only on three pumps were cup leathers replaced. The remaining 30 rehabilitated boreholes have not been visited since October 1982.