THE REPUBLIC OF THE SUDAN

WESTERN SAVANNAH DEVELOPMENT CORPORATION

in co-operation with

THE NATIONAL WATER CORPORATION

WATERYARD OPERATIONS

REPORT BY THE SYSTEMS ADVISER

PROPOSED WATERYARD MAINTENANCE SYSTEM

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1. OBJECTIVES AND SUMMARY

1.1 Objectives

Under the Technical Assistance provided to the National Water Corporation (NWC), the Overseas Development Administration (ODA) appointed two advisers with terms of reference to prepare and implement a new maintenance system for the equipment in the wateryards throughout the Western Savannah Project area.

The principal task of the Sytems Adviser is to design and develop the systems and procedures (together with any necessary modifications of the present NWC organisation) required for:

(a) Operation of the wateryard equipment, with regular records to monitor its performance.

(b) Routine servicing and maintenance of the wateryards (together with provision for emergency repairs and replacement) by mobile teams with workshop support.

An initial evaluation of the subject was given in the Inception Report dated February 1987, prepared by the Systems Adviser and the Operations Adviser. The objective of the present report is to record the Systems Adviser's proposals for a new maintenance system based on establishing planned preventive maintenance concepts with a supporting system for breakdown repairs.

1.2 Summary

There are 232 wateryards containing some 334 borehole pumps in the project area as shown in Figure 1. The long distances and difficult terrain make the operating and maintaining of these boreholes an onorous task.

Each wateryard has at least one pumpset operator who carries out a series of simple checks and maintenace tasks and under the present NWC maintenance system he receives back-up maintenance support from one of ten maintenance crews who are employed primarily on corrective maintenance and repair of broken-down equipment.

A full inventory of equipment in all the wateryards is being systematically checked and updated but is not included in this report. A sample of the status of a group of 22 yards as inspected in October 1987 is given in Appendix A.

It is recommended that all major operational equipment in the yards be issued with serial numbers and that these be used in all future documentation so that full histories are available in future for these pieces of equipment.

The proposed maintenance system would transfer the emphasis from repair of breakdowns to planned preventive maintenance and planned corrective maintenance with strictly enforced routine maintenance at intervals of sufficient frequency to eliminate the need to risk breakdowns by running equipment when it needs adjustment and other maintenance attention.

The system proposes the upgrading of the role of the pumpset operator. Daily and weekly checks and minor maintenance tasks are defined. His competance in doing them must be checked and hopefully his skill can be improved by on-the-job training to carry out additional tasks including changing crankcase oil of the pump engines after the prescribed number of pumping hours.

It is proposed that the ten existing NWC maintenance crews be re-organised into 13 slightly smaller crews and each crew be assigned to two routes each comprising about 12 borehole units (or about 9 wateryards). The teams would travel round the yards in a pre-determined order completing each route in under two weeks. The tasks to be carried out at each wateryard would be pre-determined and shown on the annual planning chart, an example of which is given in Figure 5. The detailed work content of each task would be listed on work sheets, examples of which are given in Appendices B1 to B11.

The same planning charts and work sheets would form the basis of the improved management and reporting system which is also required.

The Systems Adviser's opinions are given about the selection of the servicing routes. The servicing crews would be organised from each of the three servicing centres at Buram, Ed D'ein and Abu Gabra. Routes with a 'mix' of 12 month, 8 month and 6 month open yards have been proposed and are shown on Figures 2, 3 and 4. However, it is important that social factors affecting the members of the maintenance crews should be taken fully into consideration and the final selection of routes must be made in conjunction with the Advisers by the NWC senior staff at each servicing centre.

It is assumed that the new workshop at Abu Gabra will be brought into full use in the near future.

Using the existing allocation of wateryards to servicing areas, the selection of routes would result in the following:

- 8 routes operated from Ed Da'ein using 4 crews
- 8 routes operated from Abu Gabra using 4 crews
- 10 routes operated from Buram using 5 crews

  Total - 13 crews

It is proposed that there should be one additional maintenance crew at each centre to carry out special tasks which could not be covered by the crews allocated to routes without disrupting their maintenance programme.

The proposed re-organisation from 10 crews to 16 (maximum) crews could be carried out without increasing the number of mechanics but there would be a need for an increased number of vehicles and quantities of supplies and spare parts during the initial period when preventive maintenance is being introduced and before the benefits of the improved maintenance become effective.

It is suggested that the proposals should be introduced initially on a model basis.

Although the priority task of the maintenance teams will be preventive maintenance of the pumps and motors, they would also carry out inspections of all installations and as much corrective maintenance as their time schedule permits. Back-up teams would carry out any building and civil works maintenance required.

Comments are made regarding distribution of fuel and training but these aspects require more detailed study by the Systems Adviser and the Operations Adviser.

Following review and acceptance of the proposals given in this report, the Systems Adviser will work with the NWC in the preparatory planning for the implementation of the proposals starting with the detailed planning of the selected model route or routes.

2. EXISTING SITUATION

2.1 Geographical Locations

Within the project area as shown on Figure 1 there are 232 wateryards containing some 334 borehole pumps of similar types.

The principal town is Nyala with regional servicing centres being located at Buram in the south-west, Ed Da'ein in the east with Abu Gabra serving the south-eastern parts of the project area. At all these places there are workshop facilities, although the facilities at Abu Gabra have yet to be brought into full use. It is understood that there are future plans to set up additional service centres at Furdus and Adila to strengthen the maintenance effort.

The provision of regular maintenance visits is rendered more difficult by the remoteness of some of the wateryards and the extremely difficult terrain for vehicle use. In many cases the distant yards are a day's drive from the service centre; but in parts of the project area the yards are close enough to enable several yards to be visited and inspected per day.

2.2 Installed Equipment

In the main there are two engine and pump combinations, as follows:

Lister 8-1 diesel engine (UK) driving an EDECO (UK) borehole pump

Torpedo (Yugoslav) diesel engine driving an SBS (Austrian) borehole pump

There are, in addition, some Deutz, Slavia and Bukh engines, together with some Adler, Grundfoss, Godwin and Mono pumps. All of these additional engines and pumps are in very minor quantities.

In probably more than 95% of the installations the equipment is either Lister/EDECO or Torpedo/SBS.

The high level storage tanks in the main come from Yugoslavia, the UK and India.

The existing inventory of the equipment in the yards is being systematically checked and updated by the Systems and Operations Advisers.

However, the existing information does not give serial numbers of the individual pumps, engines and other items of equipment. Serial numbers should be given to all major equipment items so that records can be maintained of the hours operated and the frequency of maintenance and repairs carried out on it.

2.3 Existing Maintenance Arrangements

Each wateryard has a resident staff which includes at least one pumpset operator. These operators are responsible for the running of the engines and pumps and carry out a number of daily equipment checks and minor maintenance duties. The pumpset operator's level of skill is variable as indicated by the differing standards seen at different pump houses, but it is proposed that a programme of training should be given to ensure that all pumpset operators can achieve the requisite minimum standard of skill to operate the equipment correctly and carry out the prescribed daily checks and minor maintenance tasks.

At the present time, servicing, maintenance and ad hoc repairs are carried out by NWC using ten servicing crews which, generally, include five mechanics per crew.

In addition to the above, the pump servicing crew may be accompanied by NWC staff who will undertake civil works, when it is known that this type of work is required to be carried out.

In the present system the 232 wateryards are divided between the ten servicing crews on a geographical basis, giving each crew a group of over 20 yards for which they are responsible. An example of a typical group of yards (or route) which is maintained by a crew from the Ed Da'ein service centre is the Abu Karinka route comprising 22 yards lying to the north-east of Ed Da'ein. The list of yards included in the Abu Karinka route and the equipment in each yard is given in Appendix A, which also includes a list of the repair work awaiting action when the yards were visited in October 1987.

The present system used by this maintenance crew is to leave Ed Da'ein and spend three to four weeks servicing and carrying out emergency repairs to the wateryards in and around Abu Karinka which make up the Abu Karinka route. Abu Karinka, which has a rest house is generally used as a base camp during this period.

3. PROPOSED MAINTENANCE SCHEME

3.1 General Criteria

With the limited sources at the disposal of the NWC, the maintenance of wateryard equipment has until now been directed primarily at corrective maintenance and repairs. The information given in Appendix A gives an example of the amount of repair work outstanding in a typical group of wateryards.

Although the need for this amount of repair work will continue to dominate NWC's maintenance programme for some time in the future, the urgent requirement is to emphasise the concept that planned preventive maintenance should be introduced and given appropriate priority of resources until it is universally practiced throughout the project area.

3.2 Planned Peventive Maintenance

A planned preventive maintenance system comprises generally a series of recommendations relating to the frequency at which certain maintenance procedures should be carried out in order to minimise wear and deterioration of the plant by keeping it at its best level of operating efficiency and at the same time preventing, as far as is possible, any breakdowns.

The component parts of a planned preventive maintenance scheme for the wateryard equipment are:

(a) Work Sheets

These are prepared for each piece of equipment and list the maintenance tasks to be carried out at specific intervals.

Examples of work sheets proposed for the most numerous items of equipment are given in Appendix B, divided into work sheets for daily and weekly checks to be carried out by the pumpset operators in Appendices B1, B2 and B3 and work sheets for longer interval maintenance which would mostly be carried out by touring maintenance crews which are given in Appendices B4 to B11.

(b) Planning Charts

These are used for the overall planning of the work to be carried out from each of the service centres. They give a list of the equipment at each borehole unit and show the requirement for maintenance for each category over a period of at least one year. As the number of borehole units covered by each service centre is over 100, each service centre would require a number of charts each covering a convenient number of wateryards in appropriate groups or routes (see below).

Copies of the approriate planning charts would be issued to the maintenance crews assigned to the work so that they (and the service centre managers) have a clear idea of their work programme for a prolonged period.

An example of a typical planning chart for four borehole units each with EDECO pumps and Lister engines is given in Figure 5.

(c) Allocation and Management of Maintenance Staff

Ideally the planned preventive maintenance for the wateryard equipment should be carried out by a resident mechanic with the necessary level of skill and the tools, equipment and spare parts to do all the work required; and it is suggested that this should be the ideal to which NWC should aim in the long term. As it is unlikely that this can be achieved quickly, the system which is proposed for introduction would depend on the pumpset operators reaching a level of competence and reliability to carry out the daily, weekly and fortnightly maintenance duties but backed up by visiting maintenance crews. These crews would carry out the monthly, quarterly and six-monthly preventive maintenance tasks together with planned corrective maintenance and, if appropriate, some repair work as and when necessary, as long as they have the time and capabilities to do these repairs without neglecting or disrupting their preventive maintenance schedule. At the same time these crews would give on-the-job training to the pumpset operators who would gradually increase their level of involvement towards the ideal mentioned above.

(d) Reporting and Supervision

During each preventive maintenance task it is essential that the mechanic carefully inspects the item for signs of abnormality or deterioration in condition and that all such signs are clearly noted and reported to the maintenance manager for appropriate action. The work sheets given in Appendices B4 to B11 include space for inspection notes and also for reporting on spare parts and materials used in the maintenance task. It is suggested that these work sheets are completed in triplicate, the top copy to be passed to the maintenance control manager at the service centre, the other two being kept by the pumpset operator and the maintenance crew leader respectively. These copies can therefore be inspected by the maintenance supervisor when making supervisory spot-checks at any wateryard or maintenance team.

3.3 Frequency of Servicing

The frequency of servicing for diesel engines should be based upon the specified frequency for the change of crankcase oil where the Lister engine requires an oil change at every 250 hours whereas the Torpedo engine can tolerate an oil change at an increased frequency of 500 hours.

In the maintenance system which is proposed it is assumed that the resident pumpset operator will have the ability to carry out oil changes and that he will carry out alternate oil changes (the 250 hours schedule for a Lister engine) thereby extending the time between visits of the maintenance crew to correspond to double the oil change time period. Therefore, where a Lister engine is fitted the maintenance crew will visit every every 500 hours and where a Torpedo engine is fitted the maintenance crew will visit every 1 000 hours. Where a wateryard has two boreholes the two installed engines (and all other equipment) will be serviced during the same visit.

The frequency of visits will depend upon:

(a) the frequency of oil change, either every 500 hours for a Lister engine or every 1 000 hours for a Torpedo engine

(b) the hours operated per day which can be as high as 20 hours per day

(c) the seasonal utilisation of the wateryards where some pumps operated for all twelve months of the year, while others operate for eight or six months of the year

As a general approximation, one-third of the wateryards mostly in the more northern locations, operate during every month of the year, another one-third of the wateryards operate for about eight months of the year, while the remaining third of the wateryards, mostly in the southern locations operate for only about half the year. This means that the wateryards in the drier northern areas will require greater maintenance attention throughout the year than would be the case with the pumps in the south. During this period of pumping inactivity in the southern areas the opportunity can be taken to carry out major overhauls.

3.4 The Size of the Pump Servicing Programme

The overall extent of the servicing programme can be assessed from the basis that the maximum number of pumps to be maintained is about 340.

If 34% of these pumps operate 52 weeks per year, 33% operate for 35 weeks per year and 33% operate for 26 weeks per year, the total number of pump operating weeks per year is 13 063, which at a maximum operation of 20 hours per day gives 1 828 820 hours per annum.

Approximately 50% of the pumps require maintenance crew visits every 500 hours (Lister engines) and 50% require visits every 1 000 hours (Torpedo engines), therefore the maximum number of maintenance visit is:

$$\frac{914\,410}{500} + \frac{914\,410}{1\,000} = 2\,743$$

It is assumed that a maintenance crew on average can service one pump per day for 200 days per year then the number of crews required would be in the order of fourteen.

An alternative approach is outlined in Section 3.5, in which the servicing programme is divided into the 'servicing route' concept which leads to a need for 13 servicing crews to cover the 232 wateryards.

3.5 Planning the Servicing Routes

Having made an approach to determine the size of the problem in the previous Section 3.4, an alternative approach has been adopted by the study of servicing routes, the maintenance crew taking in a group of pumps in a circular tour, using the service centre as an operating base.

From the experience gained by the Systems Adviser from field visits it is proposed that:

(a) the duration of the tour will be about two weeks

(b) on average, one pump per day will be serviced

(c) that each route to consist of approximately ten to twelve pump installations or approximately nine waterways and that one servicing crew will cover two routes, operating on each route alternatively.

Allowing for rest days, restocking and vehicle servicing, each pump could be visited at a frequency of about once in 40 days. If a Lister engine was operating for 15 hours a day then in 40 days a running time of 600 hours will have been built up. During this period the resident pumpset operator will have carried out an oil change. This, on the face of it, appears to be a very tight programme but, if need be, the resident pumpset operator could carry out a further 250 hour oil change.

By using this approach for the design of routes, it is proposed that eight servicing routes should be operated from both Ed Da'ein and Abu Gabra, requiring four servicing crews to be stationed at each of these servicing centres. From the Buram servicing centre ten servicing routes can be operated involving five servicing crews.

This approach to cope with regular servicing will involve not less than thirteen servicing crews and ideally with an extra crew to cover major repairs at each servicing centre the total number could be sixteen.

Figure 1 shows the whole project area with Figures 2, 3 and 4 showing the planned servicing routes from Ed Da'ein, Buram and Abu Gabra respectively. It should be noted that the yards to be serviced by the three servicing centres (Ed Da'ein, Buram and Abu Gabra) under the new proposed route system are already being serviced from the same servicing centres under the existing NWC maintenance system which is also organised on a geographical basis. The new system substitutes constantly moving teams in place of teams which operate a mainly on-demand corrective maintenance system.

The above proposals indicate that an increased number of maintenance crews is required. However the existing ten crews include 4 or 5 mechanics in each team (giving a total availability of almost 50 mechanics). These could readily be re-assigned at 3 mechanics per crew to enable the increased number of teams to be established without an increase of trained staff.

Clearly the re-organisation of the crews will take some time as it is important that the new system should be accepted amicably by all the personnel and it is therefore suggested that a model of the system should be set up initially for a few groups of yards. If, for example the Abu Karinka route (see Appendix A for details) was selected for the Ed Da'ein centre model, the 22 yards (30 maximum borehole units) could possibly be divided into two routes each of about 11 yards or 15 borehole units which is slightly above the planned number per route. However these routes do not include the very long journeys involved when visiting the remote wateryards in the south of the project area.

Although the number of skilled personnel required should not need to be increased, the introduction of the proposed maintenance system with 16 maintenance teams will in theory result in a requirement for 8 more vehicles, assuming each team requires one Land Rover and one truck. There would also be a corresponding increase in the materials and spare parts required over the initial period as the preventive maintenance system is introduced throughout the project area, but in the longer term, the overall maintenance costs should gradually decline as the benefits of improved training of pumpset operators and of improved maintenance, resulting in keeping a larger percentage of pumps operational without the need for the more costly breakdown repairs, spread across the project area.

3.6 Alternative Model Selection

The Abu Karinka route was originally selected as suitable for adoption as a model for the new system, primarily because it could be adopted by an existing maintenance crew with minimum disruption and change. This is an important consideration.

On the other hand there are specific advantages in adopting routes which contain a 'mix' of yards which are operated for different periods so that a crew will have some yards which can be omitted when they are seasonally closed. Figures 2, 3 and 4 show the project divided into routes using this concept. One example of such a route operated from Ed Da'ein is:

Travelling southwards in the following order:

- Umm Lebanaya
- Sarhau
- Kiriu
- Abu Matariq
- Abu Auood
- El Feid Abu Nila

and on the return leg, going north, to visit the remaining wateryards on the route in the following order:

- Es Sariq
- Hibeiyil El Taror
- Far El Habil
- Keat Barra

to return to Ed Da'ein, after being out in the field for about two weeks.

Amongst the above list:

- the two most southerly wateryards are operated for only six months per year
- the adjacent two wateryards to the north operated for eight months of the year
- the remaining six most northerly wateryards are operating during every month of the year.

3.7 Other Maintenance Requirements

This report so far has dealt primarily with the frequency of maintenance for the diesel engine but, in addition, the other equipment in the wateryards must receive maintenance attention. These other assets include;

(a) pipework (connecting the pump to the storage tank and from the tank to the delivery points), taps, and animal drinking troughs

(b) borehole pump which should be serviced every three months

(c) high level storage tank which should be inspected at every maintenance visit and maintained at a frequency of once in every six months

(d) buildings, bases and surrounds to the delivery points and fences. The maintenance of these should be the responsibility of a civil works maintenance crew, and it is recommended that one such crew should operate from each of the existing service centres of Ed Da'ein Buram and Abu Gabra. However these facilities should be inspected by the regular visiting maintenance crews at quarterly intervals

These should be the responsibility of the resident wateryard staff and any leaks or breakages should be repaired immediately they occur. Additionally the maintenance crew should check these thoroughly during every quarterly visit.

3.8 Maintenance Tasks

At the present time maintenance tasks are not comprehensively defined to get the best out of an operation and maintenance management system, which is the essential part of this report, the maintenance tasks have to be defined. Once defined, the maintenance tasks must be matched by appropriate staffing levels for carrying out the tasks and for supervision.

The item requiring most of the maintenance time and the most frequent maintenance attention is the pump engine. As stated above, the manufacturers recommended maintenance schedules for the Lister and Torpedo engines start with engine oil changes after 250 hours for Lister engines and 500 hours for the Torpedo engines and it is proposed that the local pump operators should be made responsible for making these changes but that every second change should be carried out by the visiting maintenance team.

Correct preventive maintenance, however, starts with a daily check routine by the pump operator. The tasks required on the daily checks for Lister and Torpedo engines and for an EDECO pump are given in Appendices A1, A2 and A3. These and other appendices are given in a form suitable for translation into Arabic and printing for display in the pump house and for record keeping.

Appendices B1 to B5 give the tasks to be carried out every 250 hours, 500 hours and 1 000 hours for the Lister and Torpedo engines and Appendices B6, B7 and B8 cover the maintenance requirements for EDECO pumps, water storage tanks and civil works.

All these schedules are given as examples and after approval should be followed by a complete set of maintenance instructions for all items of equipment being prepared in Arabic.

Information displayed in the pumphouse as guidance to the operator should leave no doubt in his mind about the extent of his duties and responsibilities in operation and in maintenance.

For the visiting maintenance crew the pattern of maintenance should be:

Phase A	Inspection
(always undertaken)	Servicing (including oil change) Preventive maintenance (see schedule in Appendix Group B) Records and reporting to headquarters On-the-job training
Phase B	Return to undertake planned corrective maintenance if this cannot be undertaken as an extension of the tasks in Phase A.
Phase C	Repairs in the event of a breakdown

Note. The concept of preventive maintenance taking priority over breakdowns should become accepted by NWC.

3.9 Planned Corrective Maintenance

This report has, essentially, dealt with preventive maintenance which, for the borehole engine arid pump has to be carried out on a regular basis in keeping with the running time.

Most of the attention will be given to the maintenance of the engine, based upon the hours between oil change, but, in addition, consideration must be given to planned corrective maintenance which, for the engine, can be considered as:

- decarbonising (decoking), (with associated tasks)
- re-ringing of the piston (with associated tasks)
- engine rebuild

There is a wide variance of opinion in connection with the running time at which this planned corrective maintenance should be carried out. In addition the frequency of this remedial maintenance work will depend upon the effectiveness of the routine preventive maintenance programme.

There is also, on the face of it, a choice of where this planned maintenance should be carried out, either in the pumphouse or at the base workshop. Two conflicting problems need to be taken into consideration, namely adverse site conditions (especially sand, dust and general lack of cleanliness) at the pumphouse and secondly the difficulty in handling and transporting complete engines without damage in transit. Clearly it is advisable that the top overhauls involving decarbonising or the cylinder head and the re-ringing of the piston should be carried out in the pumphouse and special precautions must be taken to prevent dust particles entering the engine.

It is equally advisable that engine rebuilding should be carried out where better facilities occur, namely at the base workshops, and means must be evolved to ease the lifting and transportation problems associated with complete engine assemblies.

The minimum requirements for this planned corrective maintenance based on Lister engine performance could be considered as follows:

Task	Interval under worst conditions (1)	Internal under good regular maintenance (2)
Top overhaul and decoke	Every 1 000 hours	Every 2 000 hours
Top overhaul, decoke and piston ring change	Every 2 000 hours	Every 4 000 hours
Engine rebuild	Every 4 000 hours	Every 8 000 hours

It is to be hoped that the close intervals in column (1) above will not be necessary. It is suggested that top overhauls are initially done at every 1 000 hours and if the engines do not show much build-up of carbon or other signs of deterioration, the intervals could be increased gradually towards those shown in column (2).

It is also envisaged that as the preventive maintenance system, as outlined in this report, becomes implemented and is successful, then the general condition of the pumping equipment will substantially improve, compared with its present condition. As a result engine reliability, for example, will increase and, from a higher level of reliability, will come an overall decline in running hours with more wateryards remaining serviceable and a consequential reduction in the preventive maintenance needs by increased time intervals between the 500 and 1 000 hours servicing routines.

In outlining these proposals there remains the problem of how to handle the engines (and other equipment) where no cranage is available to lift the engines on to the deck of a truck at the wateryard.

Some of the problems associated with the carrying out of top overhauls at the pumphouse could be alleviated by increased cleanliness and protection from airbourne sand. The provision of exchange heads, for example and also the availability of reconditioned injectors would reduce the time spent in the pumphouses. More planning in planned maintenance would, in every respect, pay-off in terms of operational benefits.

3.10 Distribution of Fuel

At the present time fuel is distributed by barrels and this method is expected to continue.

The maintenance system described in this report increases the number of touring servicing crews from ten to thirteen. These crews will be away from base for periods of up to about two weeks and during this period they will have to transport all their equipment and supplies. This will, of necessity, involve the use of truck and a vehicle of this capacity will additionally be able to carry supplies of fuel in barrels.

Although this will be beneficial in providing some distribution of fuel there will still be a need to utilise additional trucks to deliver fuel to wateryards, whether this be by tanker truck or by barrels.

The frequency and balance of barrel and bulk fuel deliveries can be one aspect that can be more fully studied in the model route, the details of which have already been outlined above.

3.11 Training

The success of the proposed maintenance system will largely depend on the skill levels of the pump operator and of the maintenance crew personnel and a training programme is required to improve these skills where necessary and to introduce the new procedures and routines of the proposed maintenance system.

At the wateryards the training of the resident pumpset operator in the basic maintenance tasks is the corner stone of the maintenance system. As these operators are widely scattered throughout the project area, their training must inevitably be given by on-the-job methods through the visiting maintenance teams. Ideally, therefore one member of each visiting crew should be given this responsibility and given instruction and guidance himself on how best to pass on his knowledge and skills. Thus a training of trainers programme is required.

Emphasis is clearly needed on the pump and engine maintenance and advantage should be taken of assistance in training offered by the manufacturers and their Sudanese agents. The present situation in other areas of training also needs upgrading, for instance in vehicle maintenance and in he rebuilding of diesel engines at the service centres, where the training of store keepers should also be included in the training programme. The Systems Adviser has also observed that there is an urgent need for training in the use of machine tools where it would be of benefit for this specialist training to be part or a package for training in general workshop practice where the acquisition of other specialist skills for instance in:

- welding
- overhaul of fuel injection equipment
- reclamation of spare parts
- stock control

can all be part of a planned training programme.

3.12 Management and Supervision

An approach to some management controls was made as part of the Inception Report, where details were presented for the job card and stock card, the equipment data sheet and the staff communications structure.

The effective management of the new maintenance team will depend on:

- comprehensive pre-planning of all operations
- thorough record keeping and reporting
- effective back-up support from the servicing centre workshops and stores

The documents prepared by the Systems Adviser and contained in Appendices B1 to 11 and in Figure 5 are proposed as the basis of the management documentation. Following approval of this basic concept, additional documents will be drafted and the question of management of stores issues and control will be studied and an appropriate system devised.

Supervision of the maintenance system would be carried out by the chief maintenance engineer at each servicing centre. He would delegate responsibility to the maintenance crew leaders but would also be required to carry out frequent supervisory visits and spot checks to ensure that the planned programmes are being followed and that the work carried out is to the necessary standards.

3.13 Staff and Facilities Required

As stated above, it is believed that the total number of mechanics available within the NWC will be adequate to staff the proposed 16 maintenance crews. The appointment and training of the mechanic in charge of each crew is of course of crucial importance and the number of supporting personnel travelling with each crew should be kept to an absolute minimum. Helpers should be engaged locally at each wateryard.

Mechanics who are members of the touring maintenance crews should also have regular spells of duty in the service centre workshops where the reconditioning of equipment, servicing of vehicles etc. takes place.

It is assumed that the workshop at Abu Gabra will be brought into full use in the near future.

A check is required on the number and quality of tools available for use by the resident pumpset operators and all other maintenance personnel and further supplies of tools should be ordered and issued if required.

The vehicle requirements for the above maintenance programme comprise a minimum of 16 trucks and 16 Land Rovers for the mobile maintenance crews with additional vehicles (say 4 trucks and 4 Land Rovers) to cover the supervisory and supporting staff at the servicing centres.

APPENDIX A

WATERYARDS MAINTAINED BY NWC ON THE ABU KARINKA ROUTE
(as inspected in October 1987)

Wateryard identification	Pumpset installation (engine/pump)	Tank	Defects recorded
Number 15 Abu Karinka	A-Lister/SBS B-Lister/EDECO	Braithwaite	Six taps broken
Number 36 Lakhokh	Torpedo/SBS	Geotechnika	Not operational for six months Screens blocked with fine sand Six taps broken Two troughs to be re-installed
Number 153 Abu Agaba	Torpedo/SBS	Geotechnika	Engine requiring overhaul Sucker rods are bent Pump base frame is broken Fence requires repair One trough to be re-installed Six taps broken
Number 101 Abu Hafula	A - No engine/no pump B - Torpedo/SBS	Geotechnika	Rising main dropped down the borehole (22 pipes x 15 feet) Fence requires repair Six taps broken
Number 154 Eyal Balal	Torpedo/SBS	Jessop of India	Sucker rods broken Fence requires repair Six taps broken One trough to be re-installed
Number 108 Bade	Lister/EDECO	Jessop of India	Pipe has dropped down the bore Troughs to be re-installed Six taps broken Wateryard to be rehabilitated

APPENDIX A (cont.)

Wateryard identification	Pumpset installation (engine/pump)	Tank	Defects recorded
Number 109 Kafrinkola	Torpedo/SBS	Geotechnika	Six taps broken Fence requires repair Two troughs leaking
Number 225 Assahab Hassaballa	Lister/EDECO	Jessop of India	Six taps broken Tank corroded and leaking
Number 103 Sheik Hamouda	Torpedo/SBS	Geotechnika	Six taps broken
Number 141 Gaberona	A - No engine/no pump B - Torpedo/SBS	Geotechnika	Six taps broken Fence requires repair One trough missing
Number 38 Umm Serei	A - Torpedo/SBS B - No engine/SBS	Geotechnika	One trough missing Engine to be replaced
Number 139 El Ta Alba	A - Lister/EDECO B - Torpedo/SBS	?	Engine not operational since May 1987 Pump house floor collapsing Six taps broken Fence requires repair
Number 106 Habib Suleiman	Lister/EDECO	Jessop of India	Fence requires repair Six taps broken Three troughs to be re-installed Wateryard not operational for one year Rising main has dropped down the bore
Number 102 El Nair	Torpedo/SBS	Geotechnika	Six taps broken
Number 107 Abu Kungari	Torpedo/SBS	Jessop and Co. of India	Fence needs repair Six taps broken Two troughs to be re-installed

APPENDIX A (cont.)

Wateryard identification	Pumpset installation (engine/pump)	Tank	Defects recorded
Number 104 El Buweitil	Torpedo/SBS	Geotechnika	Six taps broken
Number 41 Meriood El Shurab	Torpedo/SBS	Local Sudanese Tank	Fence needs repair Six taps broken Two troughs to be replaced
Number 155 El Bobaya	Torpedo/SBS	Geotechnika	Fence needs repair Six taps broken Two troughs to be re-installed
Number 140 Gad El Sid	A - No engine /EDECO B - Lister/SBS	Jessop and Co. of India	Six taps broken One trough to be re-installed (yard rehabilitated in 1984)
Number 79 Saba El Nima	Lister/SBS	Rigwa of Egypt	Fence needs repair Six taps broken
Number 152 El Khitma	No details known		Yard not operational in October 1987
Number 151 El Luweibid	No details known		Yard not operational in October 1987

APPENDIX B.1

NWC

OPERATOR'S CHECK LIST

FOR

LISTER 8-1 DIESEL ENGINE

Daily

1. Check supply of fuel.
2. Check for leakage of oil, water and fuel.
3. Check level of lubricating oil in crankcase and top up if required.
4. Check oil around valve stems.
5. Check oil in push rod cups.
6. Turn grease cups.
7. Check cooling water circulation.
8. Check water temperature after engine has been running for a period.
9. Check colour of exhaust smoke.
10. Check lubricating oil circulation.
11. Keep engine clean.

Weekly

In addition to the daily check to carry out the following:

12. Clean air filter.
13. Check tightness of all nuts.
14. Check when the next oil change should be undertaken (at every 250 hours).

Note: This check list is to be displayed in the pumphouse for easy reference by the pumpset operator.

APPENDIX B.2

NWC

OPERATOR'S CHECK LIST

FOR

TORPEDO T111 GSA DIESEL ENGINE

Daily

1. Check supply of fuel and fill tank if necessary.
2. Check for leakage of oil, water and fuel.
3. Check level of oil in crankcase and top up if required.
4. Lubricate valve guides.
5. Lubricate rocker arms.
6. Check water level in water tank and top up if required.
7. Check cooling water circulation.
8. Check cooling water temperature after engine has been running for a period.
9. Check colour of exhaust smoke.
10. Clean air filter.
11. Keep engine clean.

Weekly

In addition to the daily check to carry out the following:

12. Clean fuel filter.
13. Check tightness of all nuts and holding down bolts.
14. Check when the next oil change should be undertaken (at every 500 hours).

Note: This check list is to be displayed in the pumphouse for easy reference by the pumpset operator.

APPENDIX B.3

NWC

OPERATOR'S CHECK LIST
FOR

EDECO PUMP

Daily

1. Check for oil leakage from gearbox.
2. Check level of oil in gearbox and top up if required.
3. Clean crankpin grease nipple and refill with Shell Alvania R3 grease.
4. Keep pump clean.

Weekly

In addition to the daily check to carry out the following:

5. Clean pitman upper bearing grease nipples and grease with Shell Alvania R3 grease.
6. Clean sampson post bearing grease nipples and grease with Shell Alvania R3 grease.
7. Check tension of drive belts.
8. Check tightness of all holding down bolts.

Note: This check list is to be displayed in the pumphouse for easy reference by the pumpset operator.

APPENDIX B.4

NWC SERVICE CENTRE

ED DA'EIN

Wateryard number: Location: Borehole:

Week number: Commencing: Preventive maintenance frequency: Every 250 hours

Engine type: Lister 8-1

NWC equipment number: E.....

Work to be carried out	In order	Not in order	Not applicable
1. Check supply of fuel in tank			
2. Check for leakage of oil, water and fuel. Attend to leaks where necessary			
3. Check cooling water circulation			
4. Check cooling water temperature			
5. Check colour of exhaust smoke			
6. Stop engine			
7. Change crankcase oil (4.5 pints of SAE 30)			
8. Turn grease cups			
9. Clean air filter			
10. Check tightness of all nuts			
11. Apply drop of oil to governor linkage and fuel pump side window			
12. Check tension, alignment and condition of drive belts			
13. Drain moisture trap in exhaust pipe			
14. Lubricate auxiliary machinery			

Work to be carried out (cont.)	In order	Not in order	Not applicable
15. Remove fuel injector and check fuel spray. Renew injector if necessary			
16. Start engine			
17. Check lubricating oil circulation			
18. Check oil around valve stem			
19. Check oil in push rod cups			

Note: Upon completion of this work to ensure that the equipment and work area is left in a clean and tidy condition.

Remarks

Record here quantities of lubricating oil and spare parts which have been used and note any difficulties with the engine which you have not been able to fully rectify.

Date	Description	Quantity or fault indication

APPENDIX B.5

NWC SERVICE CENTRE

ED DA'EIN

Wateryard number: Location: Borehole:

Week number: Commencing: Preventive maintenance frequency: Every 500 hours

Engine type: Lister 8-1

NWC equipment number: E.....

Work to be carried out	In order	Not in order	Not applicable
1. Check supply of fuel in tank			
2. Check for leakage of oil, water and fuel. Attend to leaks where necessary			
3. Check cooling water circulation			
4. Check cooling water temperature			
5. Check colour of exhaust smoke			
6. Stop engine			
7. Change crankcase oil (4.5 pints of SAE 30)			
8. Turn grease cups			
9. Clean air filters			
10. Clean oil bath air cleaner and renew oil (SAE 30)			
11. Inspect water hoses for condition and any obstructions			
12. Adjust valve clearance. Inlet 0.20 mm (0.008 inches) and exhaust 0.20 mm (0.008 inches)			
13. Clean lubricating oil strainer.			
14. Check tightness of all nuts.			

Work to be carried out (cont.)	In order	Not in order	Not applicable
15. Apply drop of oil to governor linkage and fuel pump side window			
16. Check tension, alignment and condition of drive belts			
17. Drain moisture trap in exhaust pipe			
18. Lubricate auxiliary machinery			
19. Remove fuel injector and check fuel spray			
20. Start engine			
21. Check lubricating oil circulation			
22. Check oil around valve stem			
23. Check oil in push rod cups			

Note: Upon completion of this work to ensure that the equipment and work area is left in a clean and tidy condition.

Remarks

Record here quantities of lubricating oil and spare parts which have been used and note any difficulties with the engine which you have not been able to fully rectify.

Date	Description	Quantity or fault indication

APPENDIX B.6

NWC SERVICE CENTRE

ED DA'EIN

Wateryard number: Location: Borehole:

Week number: Commencing: Engine change:

Engine type: Lister 8-1

NWC equipment number: E.....

Replaced by:

Engine type:

NWC equipment number E.....

Work to be carried out	In order	Not in order	Not applicable
1. Remove existing engine to the service centre for a complete overhaul			
2. Install overhauled engine brought out from service centre			
3. Remove crankcase door and fill troughs under connecting rod with oil (SAE 30)			
4. Apply oil to each oil hole in top of large end bearing			
5. Open oil filler and fill engine sump to within 12.7 mm ($\frac{1}{2}$ inch) of the top of oil filler (4.5 pints of SAE 30)			
6. Operate lubricating oil pump by hand or rotate engine by starting handle until oil flows down over main bearings and into dipper troughs			
7. Close up crankcase and fill recesses in cylinder head with engine oil (SAE 30) for valve lubrication			
8. Fill cups in push rods and tappet heads with engine oil			

Work to be carried out (cont.)	In order	Not in order	Not applicable
9. Remove brass plug near tappets and pour in 0.25 pint of oil (SAE 30)			
10. Fill rocker shaft greasers and give several turns to lubricate valve rockers			
11. Check tension, alignment and condition of drive belts			

Note: Upon completion of this work to ensure that the equipment and work area is left in a clean and tidy condition.

Remarks

APPENDIX B.7

NWC SERVICE CENTRE

ED DA'EIN

Wateryard number: Location: Borehole:

Week number: Commencing: Preventive maintenance frequency: Every 500 hours

Engine type: Torpedo TIII GSA

NWC equipment number: E.....

Work to be carried out	In order	Not in order	Not applicable
1. Check supply of fuel and refill fuel tank if necessary			
2. Check for leakage of oil, water and fuel. Attend to leaks where necessary			
3. Check cooling water level in water tank and top up if necessary			
4. Check cooling water circulation			
5. Check cooling water temperature after engine has been running			
6. Check colour of exhaust smoke			
7. Stop engine			
8. Change engine oil (SAE 30)			
9. Lubricate valve guides			
10. Lubricate rocker arms			
11. Clean air filter			
12. Check and adjust valve clearances. Intake 0.30 mm, exhaust 0.40 mm			
13. Remove fuel injector and check fuel spray. Renew injector if necessary			
14. Replace fuel filter element			

Work to be carried out (cont.)	In order	Not in order	Not applicable
15. Check tightness of all nuts and holding down bolts			

Note: Upon completion of this work to ensure that the equipment and work area is left in a clean and tidy condition.

Remarks

Record here quantities of lubricating oil and spare parts which have been used and note any difficulties with the engine which you have not been able to fully rectify.

Date	Description	Quantity or fault indication

APPENDIX B.8

NWC SERVICE CENTRE

ED DA'EIN

Wateryard number: Location: Borehole:

Week number: Commencing: Preventive maintenance frequency: Every 1 000 hours

Engine type: Torpedo T111 GSA

NWC equipment number: E.....

Work to be carried out	In order	Not in order	Not applicable
1. Check supply of fuel and refill fuel tank if necessary			
2. Check for leakage of oil, water and fuel. Attend to leaks where necessary			
3. Check cooling water level in water tank and top up if necessary			
4. Check cooling water circulation			
5. Check cooling water temperature after engine has been running			
6. Check colour of exhaust smoke			
7. Stop engine			
8. Change engine oil (SAE 30)			
9. Clean cooling system			
10. Lubricate valve guides			
11. Lubricate rocker arms			
12. Clean or replace air filter as necessary			
13. Check and adjust valve clearances. Intake 0.30 mm, exhaust 0.30 mm			

Work to be carried out (cont.)	In order	Not in order	Not applicable
14. Remove fuel injector and check fuel spray. Renew injector if necessary			
15. Replace fuel filter element			
16. Check tightness of all nuts and holding down bolts			

Note: Upon completion of this work to ensure that the equipment and work area is left in a clean and tidy condition.

Remarks

Record here quantities of lubricating oil and spare parts which have been used and note any difficulties with the engine which you have not been able to fully rectify.

Date	Description	Quantity or fault identification

APPENDIX B.9

NWC SERVICE CENTRE

ED DA'EIN

Wateryard number: Location: Borehole:

Week number: Commencing: Preventive maintenance frequency: Every 2 000 hours

Pump type: EDECO MK III M

NWC equipment number: P.....

Work to be carried out	In order	Not in order	Not applicable
1. Check for oil leakage from gearbox			
2. Change gearbox oil (4 gallons of Shell oil Vitrea 220 or Dentax 90)			
3. Clean crankpin, grease nipple and grease (Shell Alvania R3 grease)			
4. Clean grease nipples of pitman upper bearing and apply Shell Alvania R3 grease			
5. Clean grease nipples of sampson post bearing and apply Shell Alvania R3 grease			
6. Check condition and tension of drive belts (20 mm deflection)			
7. Check tightness of all holding down bolts			
8. Check condition of wire rope sling			

Note: Upon completion of this work to ensure that the equipment and work area is left in a clean and tidy condition.

Remarks

Record here quantities of lubricating oil and spare parts which have been used and note any difficulties with the pump which you have not been able to fully rectify.

Date	Description	Quantity or fault identification

APPENDIX B.10

NWC SERVICE CENTRE

ED DA'EIN

Wateryard number:	Location:	Borehole:
Week number:	Commencing:	Preventive maintenance frequency: Every 6 months

Tank type: Braithwaite in pressed steel

NWC equipment number: T.....

Work to be carried out	In order	Not in order	Not applicable
1. Inspect tank for leaks			
2. Inspect for signs of corrosion around the edges of panels			
3. Inspect condition of paintwork			
4. Inspect pipe connections to the tank			
5. Inspect tower for structural defects, such as loose bracing members, tightness of connecting bolts and holding down bolts			
6. Inspect condition and security of access ladder			
7. Inspect pipework for leaks, corrosion and security of support brackets			
8. Inspect tower foundations and replace and recompact material adjacent to the concrete slab			
9. Inspect gate valves: (a) for structural defects and damage (b) distortion of flanges and leakage (c) leakage from glands (d) free movement of valve through half a turn in each direction and lubricate the valve stem			

Note: Upon completion of this work to ensure that the equipment and work area is left in a clean and tidy condition.

Remarks

Record here spare parts which have been used and note any difficulties with the tank which you have not been able to fully rectify.

Date	Description	Quantity or fault identification

APPENDIX B.11

NWC SERVICE CENTRE

ED DA' EIN

Wateryard number: Location: Borehole:

Week number: Commencing: Preventive maintenance frequency: Every 3 months

Check of facilities: Pipework, buildings and fences

Work to be carried out	In order	Not in order	Not applicable
1. Check all pipework, valves, connections and meters for damage, leakage and corrosion. Rectify or repair as necessary.			
2. (a) Inspection of buildings, including the structural condition, paintwork and the internal and external condition of the roof (b) Subsidence and damage to foundations (c) Doors, windows, joists and load bearing timber			
3. Inspect condition of fences and gates to prevent the entry of animals. Grease gate hinges			

Note: Upon completion of this work to ensure that the area is left in a clean and tidy condition.

Remarks

Record here and overleaf any materials which have been used and note any difficulties which you have not been able to fully rectify.

Date	Description	Quantity or fault identification

APPENDIX C

EXAMPLE OF NWC EQUIPMENT DATA SHEET

NWC equipment number: E00045 Date: 16/6/87

Equipment description: Lister 8-1 diesel engine

E - Engines

P - Pumps

T - Tanks

Technical details of equipment:
Serial number 3600557 8-1 001
8 hp
Single cylinder
850 rpm

Manufacturer's name and address:
Lister Petter Co. Ltd.
Dursley, Gloustershire GL11 4HS
England
Telephone: England 04534141
Telex: 43261

Agent's name and address: Sutrac

Date equipment purchased: 19/1/87

Indent number: SP 4/1/3

Crown Agent's reference: BA3V6/307507/001 SUDUKLWSP2

Unit purchase price: £ Sterling 1 349.50

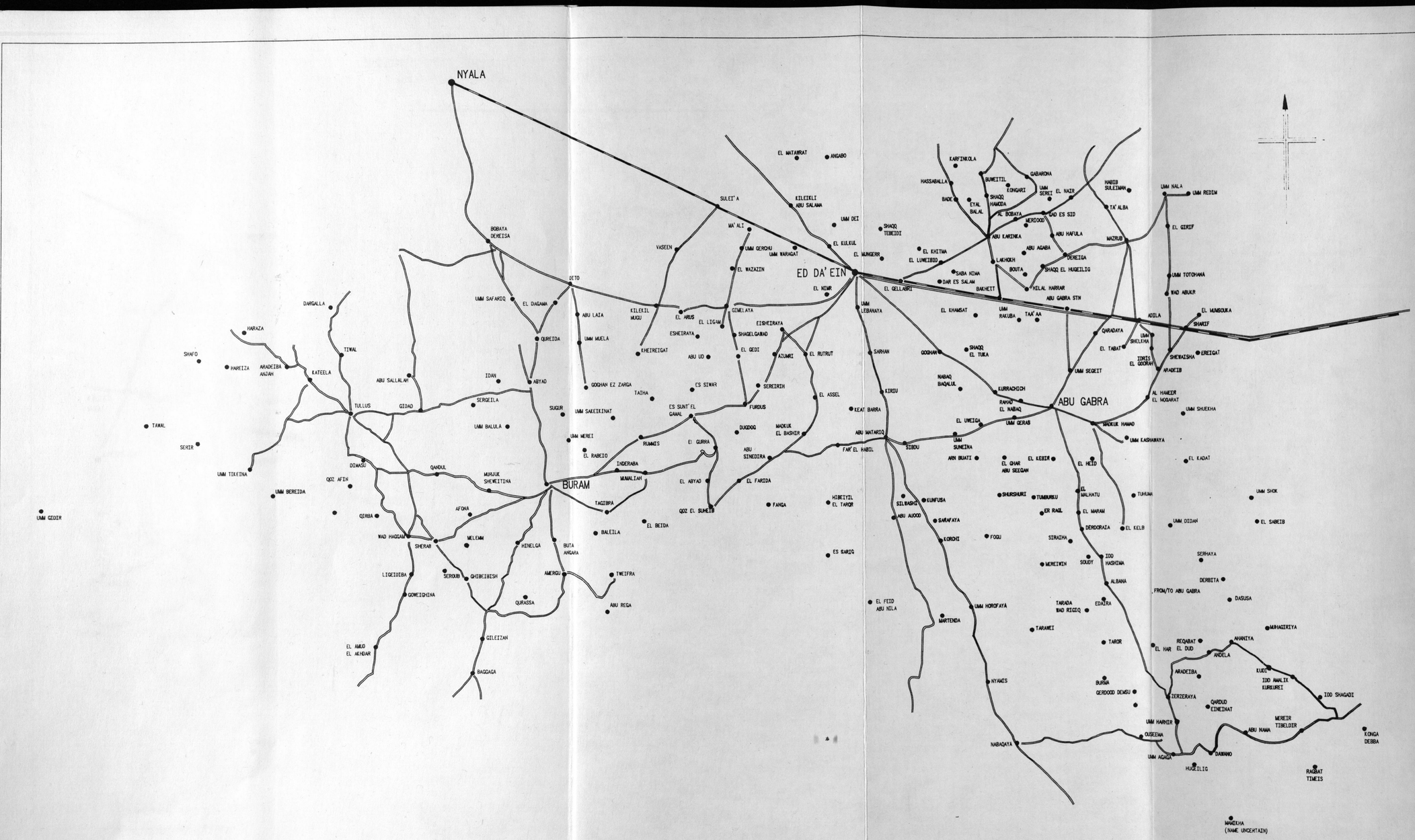
Date	Current location of equipment	Remarks
7/7/87	Al Moud Al Akta settlement	

See over page for details of breakdowns and the spare parts which have been utilised.

Date	Description	Quantity or fault indication

Figure 1

PROJECT AREA



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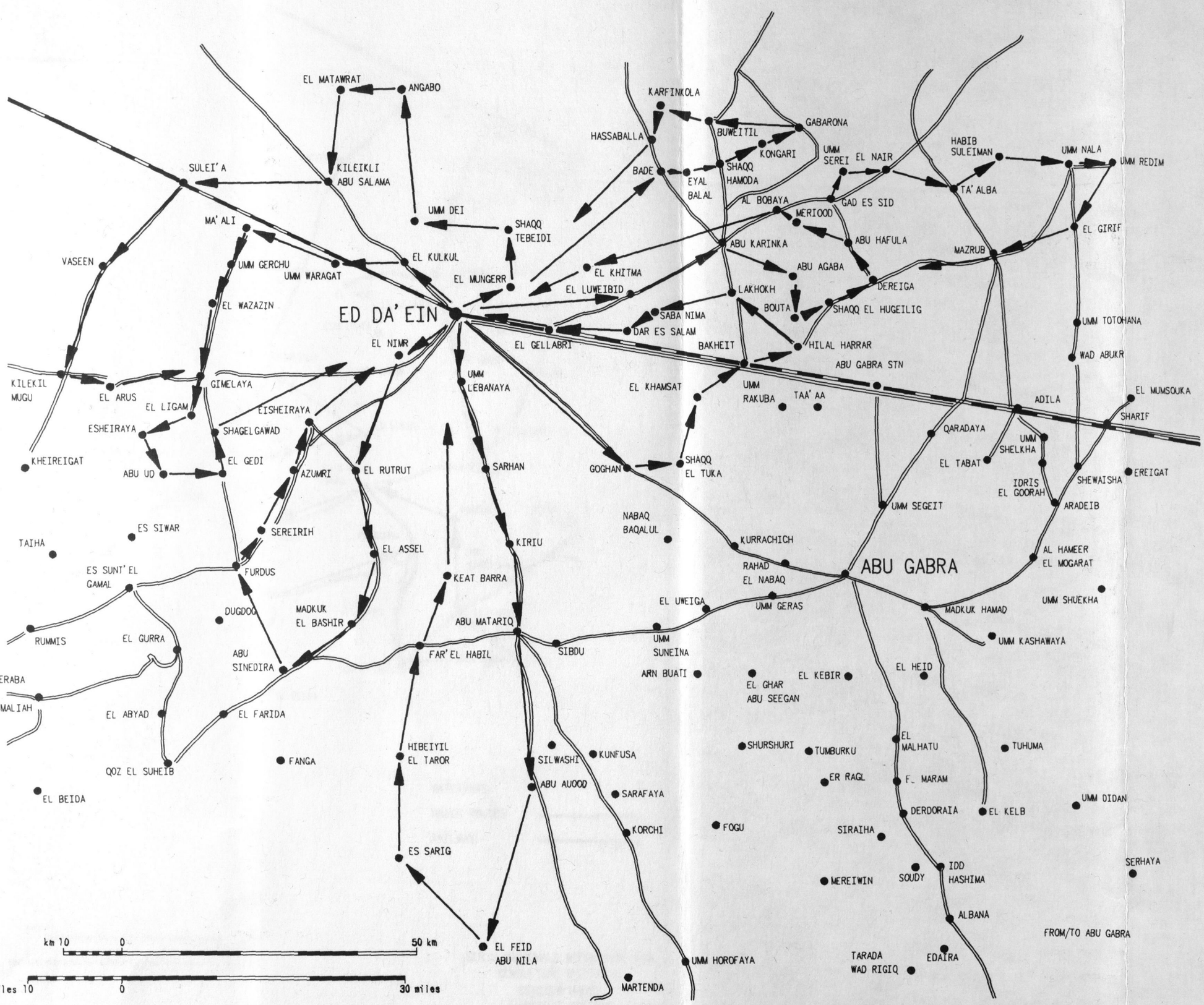
DEMETER HOUSE
CAMBRIDGE CB1 2RS
UNITED KINGDOM

Figure 2

PROPOSED SERVICING ROUTES BASED UPON ED DA'EIN



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DEMETER HOUSE
CAMBRIDGE CB1 2RS
UNITED KINGDOM

Figure 3

PROPOSED SERVICING ROUTES BASED UPON BURAM

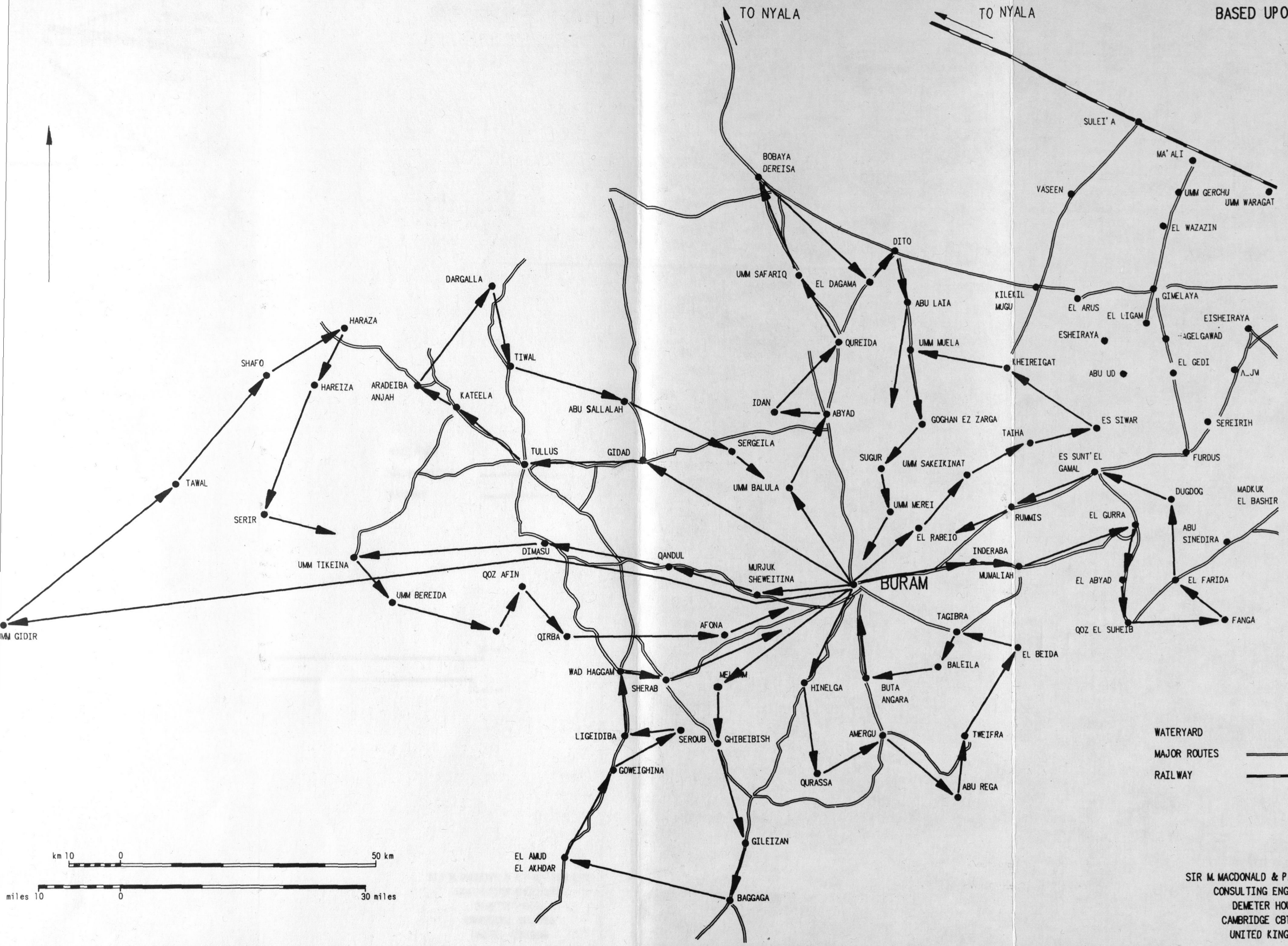

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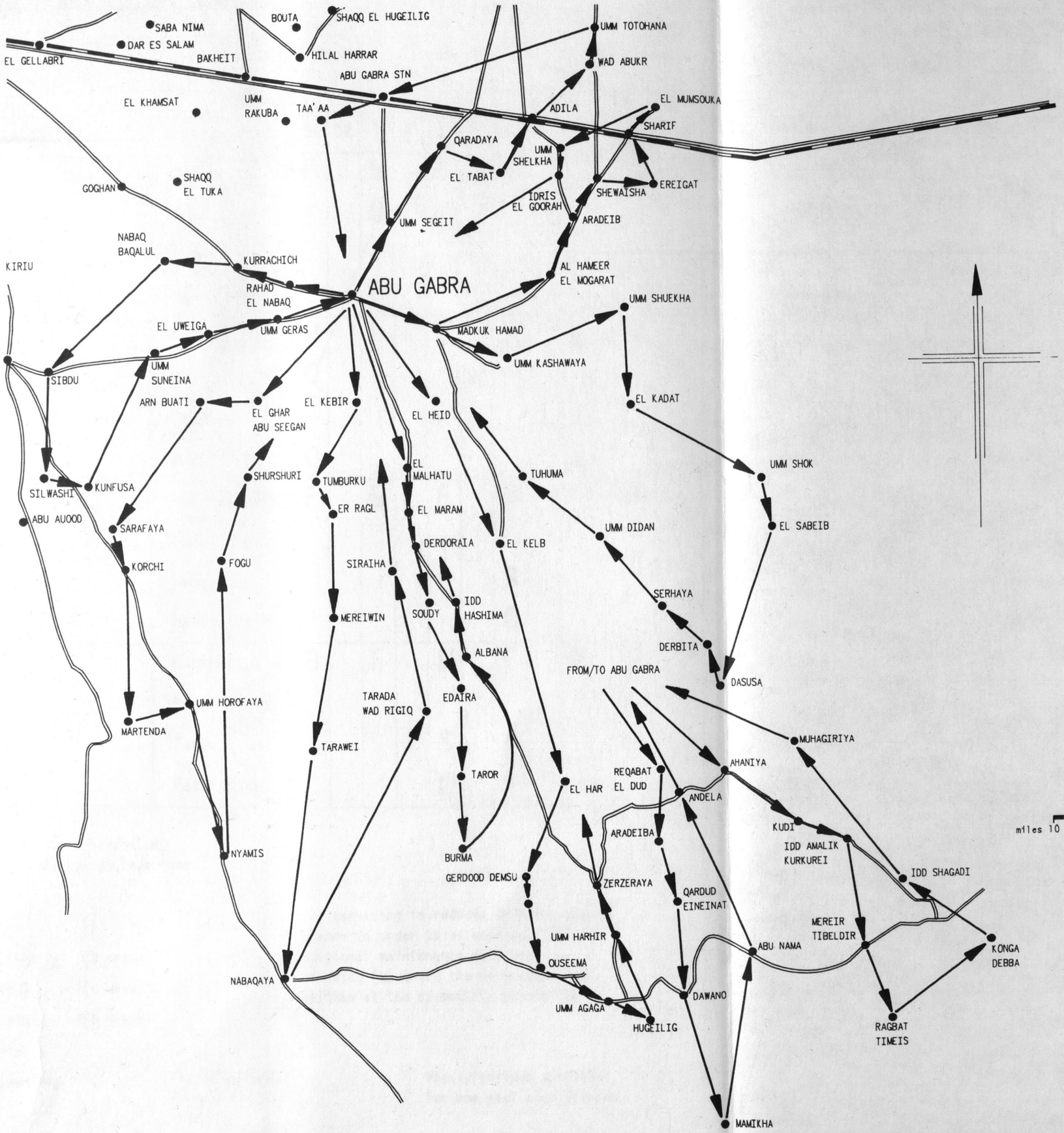
Figure 4

PROPOSED SERVICING ROUTES BASED UPON ABU GABRA



WATERYARD ●

MAJOR ROUTES ———

RAILWAY ———

km 10 0 50 km

miles 10 0 30 miles

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POSED MODEL MAINTENANCE SCHEME FOR ONE TYPICAL SERVICE ROUTE

Figure 5

In this example (showing four boreholes only) the oil change is assumed at 250 hours for a Lister engine and for this running time to accumulate in a period of about two weeks.

e identification	Equipment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9
	Engine: LISTER	M		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M
	Pump: EDECO													Q																Q																																						
	Tank:					S																																S																										S	
	Facilities:					Q																Q																Q																										Q	
	Engine: LISTER	F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F
	Pump: EDECO											Q																Q																																								
	Tank:			S																																S																										S			
	Facilities:			Q																Q																Q																										Q			
	Engine: LISTER	M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F
	Pump: EDECO									Q																Q																																								
	Tank:	S																																S																										S			
	Facilities:	Q																Q																Q																										Q			
	Engine: LISTER	F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F		B		F		M		F
	Pump: EDECO							Q																Q																																								
	Tank:			S																												S																												S			
	Facilities:			Q												Q																S																												Q			

Other boreholes follow on from here

The planning of the workload will dictate when the servicing(s) of tanks takes place – not necessarily at exactly six monthly intervals.

The frequency of quarterly servicing is reduced to eight weeks at this part of the programme in order to balance out the work load and for the additional maintenance work to coincide with monthly servicing (M) where the maintenance work to be carried out is less than at the bi-monthly period (B).

D

Fortnightly (2 weeks)
Monthly (4 weeks)
Bimonthly (8 weeks)
Quarterly
Six monthly

The actual equipment installed is intended to be listed in the column headed equipment.

Only four installations are shown plotted, but this sheet should contain all the pump installations on one route.

In this model the frequency of oil change at 250 hours (F) is carried out by the resident pumpset operator with a visit by the maintenance crew at a frequency of 500 hours (M), at 1000 hours (B) and six monthly (S).

Weekly periods are shown for one year plus 9 weeks.