PILOT STUDY TO CONSIDER THE MAINTENANCE PROBLEMS AND NEEDS IN ONE GEOGRAPHICAL AREA AND PROVIDE PRACTICAL RECOMMENDATIONS FOR ACTION FOR THE

NATIONAL WATER SUPPLY AND DRAINAGE BOARD SRI LANKA

a joint WHO and IRC collaborative study
with the participation of
Industrial Training Service, U.K.
as consultants

COLOMBO
October 1982

International Reference Centre
for
Community Water Supply and Sanitation

P.O. Box 5500 2280 HM Rijswijk
The Netherlands

ITS

Industrial Training Service Ltd.
43 Market Place
Wetherby
Yorkshire LS22 4LN
United Kingdom

PILOT STUDY TO CONSIDER THE MAINTENANCE PROBLEMS AND NEEDS IN ONE GEOGRAPHICAL AREA AND PROVIDE PRACTICAL RECOMMENDATIONS FOR ACTION FOR THE

NATIONAL WATER SUPPLY AND DRAINAGE BOARD SRI LANKA

W.T. Anderson
Senior Consultant
Colombo, October 1982

ABBREVIATIONS

AGM	Assistant General Manager
ARM	Assistant Regional Manager
B/M	Breakdown Maintenance
Chl	Chlorination
DGN	Deputy General Manager
EA	Engineering Assistant
GCE	General Certificate of Education
H/O	Head Office
HQ	Headquarters
IRC	International Reference Centre for Community Water Supply and Sanitation
ITS	Industrial Training Service
NWS&DB	National Water Supply and Drainage Board
O and M	Operation and Maintenance
OIC	Officer in Charge
RM	Regional Manager
TA	Technical Assistant
TOR	Terms of Reference
TV	Television
UK	United Kingdom
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WHO	World Health Organization

This Report is the result of a 4-week collaborative assignment between officials of the National Water Supply and Drainage Board, its World Health Organisation Institutional Support Project and Industrial Training Service Limited, United Kingdom.

The assignment was funded by the Netherlands Government through the WHO International Reference Centre for Community Water Supply and Sanitation, The Hague, as part of its overall project for the development of a national training delivery system for community water supply in Sri Lanka.

The assignment was to carry out a pilot study into the maintenance problems and needs in one geographical area, and then to propose a training plan to meet those needs.

The pilot study confirmed that action is needed in many areas - not just training - if maintenance performance is to be improved. This report therefore presents a comprehensive and wide ranging set of practical recommendations for action.

CONTENTS

PART 1 : INTRODUCTION

1.1 Aim
1.2 Background
1.3 Terms of reference
1.4 The study team
1.5 Geographical coverage
1.6 Methodology
1.7 Layout of the Report

PART 2 : FINDINGS

2.1 Maintenance organisation and practices
- 2.1.1. Existing arrangements
- 2.1.2. Observations

2.2 Description of schemes in operation and under construction in the Galle Region.
2.3 Staffing at schemes in the Galle Region.
2.4 Description of plant and equipment at each scheme
2.5 Planning and design decisions and the consequences for maintenance.
2.6 Installation and commissioning of plant and equipment and consequences for maintenance.
2.7 Summary of breakdown and preventive maintenance tasks done, May-July 1982.
2.8 Systems for recording and reporting operational, breakdown and preventive maintenance.
- 2.8.1. Existing arrangements
- 2.8.2. Observations.

2.9 Present manpower planning practices.
2.10 O and M staffing policy and practice.
- 2.10.1. Existing arrangements
- 2.10.2 Observations

2.11 Present training organisation.
- 2.11.1 Organisation chart
- 2.11.2 Maintenance training
- 2.11.3 Determining training needs.

2.11.4 Training Methods.

2.11.5 Evaluation of training.

2.11.6 The use of outside training facilities for maintenance training.

PART 3 RECOMMENDATIONS FOR ACTION

3.1 Organisation, staffing and responsibilities.

3.1.1 Responsibility for maintenance.

3.1.2 From senior management down to scheme level.

3.1.3 Within each scheme.

3.2 Maintenance Facilities

3.2.1 The Regional Workshop

3.2.2 The Regional Stores

3.2.3 The Mobile Maintenance Crew

3.2.4 Maintenance staff at individual schemes.

3.3 Systems and procedures.

3.3.1 Preventive Maintenance.

3.3.2 Planning and design decisions.

3.3.3 Installation and commissioning of plant and equipment.

3.4 Manpower planning, recruitment and selection.

3.4.1 Manpower recording, forecasting and planning.

3.4.2 Recruitment and selection policies.

3.5 Staff Management and Attitudes.

3.6 A Maintenance Training Plan.

3.6.1 Develop the Training Section.

3.6.2 Take action to start maintenance training now.

3.6.3 Set up a maintenance training centre.

3.6.4 Appoint instructors for the maintenance training centre.

3.6.5 Train key staff in the Training Section.

3.6.6 Provide consultancy help for NWS&DB on O and M management.

3.6.7 Help the Regional Manager to implement the new organisation in his Region.

3.6.8 Complete the process of clarifying jobs and writing job descriptions.

3.6.9. Design training programmes to develop the technical and supervisory skills of the OICs.

3.6.10. Design a training programme on flowmeter maintenance and repair.

3.6.11. Design training programmes for mechanics and electricians.

3.6.12. Develop a career structure which opens up prospects for all staff to be promoted.

3.7 Extending the approach to other Regions.

3.8. Action.

PART I : INTRODUCTION

1.1 AIM

This is a fairly short report. Its aim is to continue the process of bringing about practical action to solve real problems. The ideas and recommendations have been developed through regular and frequent discussions with senior management, with senior training staff and with operations and maintenance staff at all levels.

1.2 BACKGROUND

As a result of the deliberations of the National Co-Ordination Committee on Water and Sanitation, following the preparation of the Sri Lanka National Decade Plan for the Sector, the development of a manpower and training plan and recent progress made by the Training Section of the National Water Supply and Drainage Board (NWS&DB) in co-operation with the WHO Advisory Staff to the NWS&DB (WHO/UNDP Project EHP 002 - Institutional Support to NWS&DB), the NWS&DB is ready to substantially increase its training activities in order to improve the quality, reliability and continuity of its services to the population of Sri Lanka.

Maintenance, including preventive maintenance as well as rehabilitation, is being given high priority in the NWS&DB. The planning for maintenance training is to be carried out as a follow-up of the overall training plan based in the reports listed below:

1. Draft Plan - International Drinking Water Supply and Sanitation Decade, 1981 - 1991. U.S.A.I.D. and the Government of Sri Lanka.
2. Development of Sectoral Skilled Manpower for the National Water Supply and Drainage Board, Review and Plan of Action, October 1980. WHO and IRC.

3. Manpower Study and Training Plan for the Drinking Water and Sanitatation Sector, July 1981. WHO and IRC/ITS.
4. Draft project proposal to implement a National Manpower Development and Training Programme in the Water and Sanitation Sector, July 1981. WHO and IRC/ITS.

At a meeting in Spring 1982 between Mr. N.D. Peiris (Chairman of NWS&DB), Mr. D.E.F. Jayasuria (Senior DGM), Mr. D. Konchady (Project Manager, WHO) and Mr. R.E. Brasseur (Programme Manager International Reference Centre) it was agreed that IRC should fund a one-month assignment in the form of a pilot study on maintenance management, organisation and training. It was agreed that ITS Limited of UK would provide two short term consultants to assist with the work.

1.3 TERMS OF REFERENCE

(1) Make an inventory of the maintenance tasks in a limited area; study and review current standards of maintenance procedures and methods.

(2) Review previous consultants' reports in so far as they are relevant to the subject of the present study.

(3) Recommend a system for the effective management of maintenance.

(4) Recommend a job classification for maintenance personnel for each of the existing and planned water supply schemes.

(5) Estimate the manpower requirements up to 1985.

(6) Work out a training plan to meet the needs, recommend priorities.

(7) Estimate the requirements in terms of space, workshop facilities, inventory of spares (including replacement of equipment) transport and personnel for the implementation of a regional maintenance plan.

(8) Make recommendations for a generalised application of the approach described above.

1.4 THE STUDY TEAM

Mr. D. Konchady	- Project Manager (WHO), Institutional Support to NWS&DB.
Mr. W.T. Anderson	- Senior Consultant, ITS Ltd, United Kingdom.
Mr. P.R. Humphrey	- Specialist Adviser to ITS Ltd., United Kingdom.
Mr. S. de Saram	- Technical Officer, WHO.
Mrs. G. Montgomery	- Technical Officer, WHO.

The team received valuable assistance from many staff at all levels within NWS&DB, starting from the Chairman, Mr. N.D. Peiris.

1.5 GEOGRAPHICAL COVERAGE

It was agreed that the study should cover the NWS&DB Headquarters at Ratmalana and one of its eight Regions (Galle).

1.6 METHODOLOGY

The study lasted four weeks. Within the first few days it became clear to the team that most of the NWS&DB's maintenance deficiencies are well known, have been amply documented, and do not need to be reported upon in detail yet again. Given that there were to be only four weeks for the study, it was felt that the focus of attention should be:

(1) to find the main reasons for these deficiencies, and why they still persist in spite of previous studies;
(2) to develop a set of practical recommendations for improving the situation;
(3) to assist NWS&DB senior staff and advisers to begin the process of implementing the recommendations within the four week period. A workplan for the four weeks was drafted, discussed and agreed.

It was also agreed that the implementation of the workplan should follow two important principles:

Involvement : We would seek to involve NWS&DB staff and other interested parties in all aspects of the study, from beginning to end. From experience we knew that only in that way could we get sufficient commitment to implement the recommendations, and sufficient understanding to enable application of the approach to other geographical areas.

Reporting : Reporting must take place regularly throughout the study - not just at the end. We would therefore aim to set up a small Steering Group at the start to which the study team would report at weekly intervals. The main roles of the Steering Group would be to provide information, to monitor progress, to be a sounding board for ideas, to be a communication link with management and to be a force to make things happen. The Steering Group consisted of Mr. T.B. Madugalle, General Manager, Mr. D.E.F. Jayasuria. Deputy General Manager, Mr. V. Parameswaram, AGM (O and M). Others from O and M and Training were coopted as required.

1.7 LAYOUT OF THE REPORT

The Report is in three parts. The findings and recommendations of the study are presented in Parts 2 and 3 respectively. Part 3, "Recommendations for Action" is the most important and should be given the most detailed study.

Although the initial focus of the study was to be maintenance training, it soon became clear that there were major organisational problems to be solved, systems and procedures to be developed, and facilities to be specified, before "training" could be considered. The recommendations have therefore been grouped under the headings of:

Organisation, staffing and responsibilities.
Maintenance facilities.
Systems and procedures.
Manpower planning, recruitment and selection.
Staff management and attitudes.
Training.
Action.

The Report does not cover water quality management and laboratory facilities (outside the TOR) although they are required for the operation and maintenance of schemes.

PART 2 : FINDINGS

2.1 PRESENT MAINTENANCE ORGANISATION AND PRACTICES

2.1.1. Existing Arrangements

When the study began, the organisation chart for operation and maintenance, down to scheme level in the Galle Region, was as in Appendix I. Key aspects are:

(a) Centralised Guidance and Monitoring of Operation and Maintenance.

The O and M Division was created early in 1981, under an AGM (O and M) based at Headquarters, as an attempt to improve standards of operation and maintenance of water supply schemes. The creation of the Division, its staffing and its functions are as described in Section 12.2 of the Ernst and Whinney Draft Report 1982 on Organisation and Management Studies Volume I. The O and M Engineer for Galle Region is based at Galle, has two teams of mechanics/electricians reporting to him - one at Galle and one at Matara - but is apparently under the functional guidance of the AGM (O and M). See Appendix I. The operating personnel at each scheme operate directly through the ARM (O and M) to the Regional Manager.

(b) Central Workshop

The Central Workshop for NWS&DB is located at Ratmalana and is headed by a Chief Engineer who reports directly to the DGM (Supplies and Services). The major function of the Workshop is to repair and overhaul vehicles, pumps, and electrical and mechanical equipment brought in from elsewhere in NWS&DB. As well as this, Workshop personnel are sometimes sent out for repair work at the sites. There are four main sections to the workshop -

- vehicle repair and service
- pump section
- general machine shop
- electrical section

A description of the operations, equipment and personnel in each section is given in Sections 12.3.3. - 12.3.7. of the Ernst and Whinney Report.

(c) Operation and Maintenance

The country is divided into 3 Ranges. Each Range is headed by an AGM based at Ratmalana. Each of the AGMs is responsible for construction of schemes principally and is assisted by a Chief Engineer. The O and M responsibility rests with the AGM (O and M). The 3 Ranges are sub-divided into 8 Regions. In the South West Range there are 3 Regions, one of which is Galle. Each Region is headed by a Regional Manager who is responsible for construction as well as operation and maintenance of water supply schemes. The Galle Regional Manager has two Assistant Regional Managers, one for construction and one for operation and maintenance. At the Galle Regional Office there is also an Accountant and a Chemist.

There are a total of 24 water supply schemes currently in operation in the Galle Region. Nine of them are under local authority control (although in practice NWS&DB provides the maintenance service for them). The remaining 15 are under the control of the ARM (O and M). Most schemes under NWS&DB control are headed by an Officer in Charge. Three new schemes are currently under construction and there is further construction work under way at 6 of the operating schemes.

2.1.2. OBSERVATIONS

(a) Centralised Guidance and Monitoring of Operation and Maintenance.

There is a general agreement in NWS&DB that the O and M Division has failed to improve operation and maintenance standards. The main reasons have been listed in the Ernst and Whinney Report (Volume I, Section 12.5). The most important reason is the unworkable lines of command. Although the Regional Manager has ultimate responsibility for operation and maintenance of the schemes in his region, the staff who work on the schemes are administered and guided by electrical/mechanical engineers who (according to the organisation chart) report to the AGM (O and M). This has caused considerable confusion both in the Regions and in the O and M Division. A Regional Manager cannot be held accountable for the performance of his Region if another department has the authority to control his staff. One of the recommendations in the Ernst and Whinney study is that the construction and O and M functions both HQ and in the Regions should be separated.

(b) Central Workshop

Our observations regarding the performance of the Central Workshop are generally in agreement with the Ernst and Whinney Report (Volume I, Section 12.6) and need not be restated here. Our main concerns are the following:

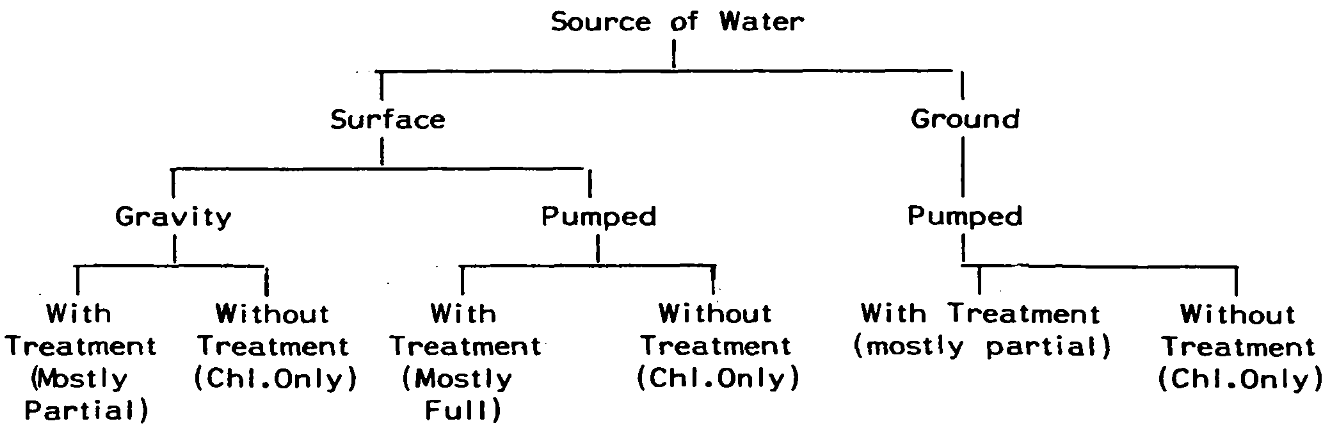
- considerable underutilisation of manpower and equipment,
- lack of sufficient skilled manpower and a very high labour turnover among craftsmen.

(c) Operation and Maintenance

Again, our observations are generally in agreement with Volume I, Sections 16.2.3/4 of the Ernst and Whinney Report. Our major concern is that the Regional Manager tends to concentrate on construction issues, at the expense of operation and maintenance. This is probably a main reason why the equipment at the schemes is not being maintained properly and is in poor operating condition. Much of the more sophisticated equipment has been broken down for some time. Structures are rusting, buildings are untidy. There is much work to do - yet many people stand still. At many large schemes, the Officer in Charge and his Technical Assistants have neither the technical knowledge - nor the supervisory experience - to manage their staff properly. At the smaller schemes, there is often no-one of sufficient seniority or ability to provide any supervision and control at all.

2.2 DESCRIPTION OF SCHEMES IN OPERATION AND UNDER CONSTRUCTION IN THE GALLE REGION

In the Galle Region, there are 24 piped water supply schemes in operation, some of which are under augmentation/improvements to one or more of the following : sources of water, treatment works and distribution systems. Three new rural schemes are under construction. Appendix 2 contains the list of schemes. In general the sources of water are either surface or ground water. The types of water supply schemes may be illustrated thus:



Five of the operating schemes are major urban schemes. Galle, Matara, Hambantota - Ambalantota and Tangalle water supply schemes have full treatment (aeration, chemical coagulation, settlement, filtration and chlorination). At Weligama, the ground water is aerated for iron removal and is chlorinated. Three of the rural schemes are of the gravity type and are only chlorinated. The remaining 16 operating schemes and 3 schemes under construction serve rural communities ranging in population from 1500 to 10,000. Largely, these schemes have ground water for source and are chlorinated. In a few cases, surface water is treated through slow sand filtration before chlorination.

The operation of the schemes is either by the NWS&DB or the local authority except in the case of Matara, where the production of water is by the NWS&DB and distribution is by the local authority. Maintenance schedules for equipment and water quality control are minimal in schemes operated by local authorities. They are deficient in the case of schemes operated by the Board. Because of this situation and the current trend to meter water connections and generate more revenue, more and more schemes are likely to be operated and maintained by the Board.

2.3 STAFFING AT EACH SCHEME IN THE GALLE REGION

Appendix 3 contains the list of schemes in the Galle Region including those operated by local authorities partially (distribution system only) or fully. The present staffing with job titles and numbers is as furnished by the Regional Manager.

It may be observed that the staffing at schemes operated by the local authorities is minimal and lacks supervisory staff, whereas in the Board - operated schemes, the numbers of staff seem adequate. However, not all the job titles are indicative of their tasks. Job descriptions are scarce, qualifications and skills of staff are generally less than desired and supervision seems inadequate. Moreover the level of staffing posted to schemes does not always correspond to the level of responsibility attached to the posts. Therefore the adequacy of staffing of schemes we are unable to judge. It seems important that each scheme be evaluated one by one and specific job descriptions and staffing levels be established.

Staff required at new schemes and at schemes under augmentation should be determined during the construction stage and also trained in advance of assumption of their duties.

2.4 DESCRIPTION OF PLANT AND EQUIPMENT AT EACH SCHEME

A description of the plant and equipment at each of the schemes in the Galle Region, except for the very small ones, is given in **Appendix 4.** This list contains the type and make of each item of plant and equipment, its present condition and its past maintenance history. Comments are also given about its condition, and any maintenance or spares problems.

2.5 PLANNING AND DESIGN DECISIONS AND THE CONSEQUENCES FOR MAINTENANCE

It seems that many schemes contain plant and equipment of a level of technology inappropriate to the situation. Such plant and equipment is often broken down, is used inefficiently, or is used not at all. Local people are not involved sufficiently in the design stage, so do not fully understand it nor, probably, do they feel much commitment to its success. Plant and equipment decisions seem often to be taken on policy grounds that are linked to foreign aid. It appears that decisions are often taken on an emergency basis, without proper consideration of all the criteria. In particular, the technical considerations of operating and - especially - maintaining the plant appear not to be given sufficient weight.

2.6 INSTALLATION AND COMMISSIONING OF PLANT AND EQUIPMENT AND THE CONSEQUENCES FOR MAINTENANCE

From the evidence available, it seems to be normal practice for a supplier to install and commission his plant and then leave. Very little effort is devoted to ensuring that NWS&DB staff are properly equipped to operate and - especially - maintain the plant. NWS&DB staff do not appear to be provided with proper training in operation and maintenance, easy to follow maintenance manuals, sets of tools or sufficient supplies of spares. As a result, breakdowns of new plant, with long delays for their repair, appear to be quite common. Spare parts seem particularly difficult to obtain.

2.7 SUMMARY OF BREAKDOWN MAINTENANCE TASKS DONE, MAY-JULY 1982

A summary of the breakdown maintenance tasks in the Galle Region over each of the 3 months May, June, July 1982 is shown in **Appendix 5.** This is a summary of the breakdowns in each month - nor a summary of all the equipment broken down at that time.

2.8 PRESENT SYSTEMS FOR RECORDING AND REPORTING OPERATIONAL, BREAKDOWN AND PREVENTIVE MAINTENANCE

2.8.1. Existing Arrangements

The present system of breakdown maintenance (B/M) reporting, implemented in May 1982, was designed with the following objectives:

(1) To keep comprehensive B/M records at site and Head Office (H/O).

(2) To provide a systematic method of checking and follow-up action by staff at H/O, on the basis of information received from site.

(3) To establish a system of breakdown information retrieval for every item of equipment.

(4) To provide a means of identification of areas of weakness in the present structure of the maintenance unit.

(5) To provide breakdown information feedback to the training division for design of more effective training courses.

(6) To provide a means of performance evaluation of maintenance staff.

The B/M system utilises the following forms:

(1) B/M notification form - This form sent by the Officer in Charge (O.I.C.) to the O and M Engineer in the region, briefly describes the nature of the problem. A copy is also sent to H/O by the O.I.C.

(2) B/M record form - this form is completed by the B/M crew during the repair. Information provided in this form includes:

   (i) preliminary report on condition of equipment prior to repairs.

   (ii) number of man-hours utilised.

   (iii) details of work done.

   (iv) cost of spares.

   (v) comments by O.I.C. and O and M engineer.

This form is submitted to the O and M engineer for his comments and signature. A copy is then sent to AGM (O and M) at H.O.

(3) Monthly B/M summary form - this form is completed by the O and M engineer and submitted to AGM (O and M) at the end of each month. The form provides a summary of the repairs carried out in the region during the month.

(4) B/M wall chart - this is maintained by the AGM (O and M) and provides "at a glance" information on the existing B/M situation, e.g., breakdowns carried over from previous month, duration of repair, time elapsed between notification of repair and commencement of repair.

Each item of equipment has a separate B/M history file wherein the B/M notification forms and the B/M record forms are filed. Reference to this file gives a complete B/M history of the particular piece of equipment.

2.8.2. OBSERVATIONS

(a) Breakdown Maintenance

(1) There is an urgent need for supervision of the work done by the maintenance crew.

(2) Lack of follow-up action at H/O on breakdowns occurring in the field. This situation could be improved by clearly defined job descriptions for maintenance staff.

(3) Need for performance appraisal of maintenance staff and maybe the introduction of an incentive scheme.

(4) Closer liaison between maintenance staff at H/O and training unit, to keep training unit informed of types of breakdowns occurring in the field.

(b) Operational Maintenance

Basic operational maintenance tasks such as oiling and greasing are being carried out satisfactorily in most plants. It is suggested that operational maintenance be formalised by the introduction of operational maintenance schedules for each item of equipment.

(c) Preventive Maintenance

Although some preventive maintenance schedules were prepared for pumps, motors and engines earlier, the system was not implemented due to existing system deficiencies (staffing, tools, vehicles for maintenance staff, etc.).

2.9 PRESENT MANPOWER PLANNING PRACTICES

No evidence was found to suggest that manpower planning in NWS&DB is significantly better now than at the time of the previous IRC/ITS study last July. This current study has focussed on maintenance and there was still found to be:

- a lack of manning standards and up to date data about existing manpower on O and M.
- inconsistencies in the various manpower returns on O and M sent to the study team.
- no systematic methods for predicting future manpower requirements.
- no records of staff turnover rates and no attempt made to predict future supply.

This lack of data has made it impossible, in the time available, to predict the future maintenance manpower requirements. The study has, however, provided management with a practical format for collecting this information.

2.10 O and M STAFFING POLICY AND PRACTICE

2.10.1 Existing Arrangements

General : The policy and practice of recruitment, selection, promotion and retention of staff for operation and maintenance in the Board follows more or less the pattern adopted for manpower on all other functions. The staff on O and M are transferable from construction to O and M and vice versa except perhaps for the semi-skilled or skilled staff working on pumping plants and treatment works.

Professional : The managerial and professional staff assigned to O and M are university graduates or those with equivalent qualification. Generally these engineers are moved in from other jobs but in certain cases, such as mechanical/electrical engineers, they are newly recruited. In these cases, they often lack the basic skills of the job and practical knowledge of field problems.

Sub-Professional : The sub-professional category of personnel engaged on O and M activities are the engineering assistants, technical assistants and foremen. The engineering assistants come from the stream of technical assistants and there are three grades. In the category of technical assistants, there are two grades. A technical assistant is recruited at Grade II with entry qualifications of G.C.E. "A" level with passes in two science subjects. In the case of Board employees, a pass at G.C.E. "O" level with 2 science subjects is also being allowed. A TA Grade II at entry requires no technical qualifications and is trained by the Board through short courses and on-the-job experience. He gets promoted to Grade TA I in two or three years depending on availability of vacancies. Entry to Engineering Assistant is at Grade II level and the entry requirements are three years as TA and pass in the sub-Inspectors (overseers) examination (alternatively 21 years as T.A. or 10 years as TA and pass in 5 subjects at the sub-Inspectors exam). Entry to EA Grade I requires pass in inspector's examination and minimum 3 years as EA II. An EA special grade with 21 years total service is promoted as engineer Grade II.

The Foreman category of staff requires pass at G.C.E. "O" level and the departmental examination prescribed for them.

Craftsmen : The staff in this category are the electricians, mechanics, welders, pipe fitters. There are two grades of electrician and two grades of mechanics. The entry level of these categories is through selection from ex-labourers who are able to read and write, and are able to pass a practical test for skills which are picked up gradually through working with a skilled tradesman. Promotion to higher grades of electrician or mechanic requires five years experience in the lower grade and passing of a practical test for skills required in maintenance and repairs. At present, there is no one in the instrument mechanic category. Also welders are few and are recruited on the basis of a departmental examination of the Government.

Semi-skilled/Skilled : In this category fall the pump operator/mechanic grades I, II, and III. Plant Attendant or Plant Operator are job titles used at treatment works for labourers performing these tasks regularly. The entry qualification for pump operators is usually the ability to read and write although of late, some G.C.E. "O" level holders are being recruited. Training is given through brief short training courses and on-the-job experience.

2.10.2 Observations

Professional : Placement in the past, of professional and managerial staff in charge of construction and maintenance jointly, has been detrimental to maintenance management and the corrective action now being taken to separate the two functions is a step in the right direction. New graduates recruited into maintenance need sufficient technical training for job. Practical experience on construction jobs initially is helpful. Many of the existing professional staff seem to require technical and management training. Staff movement in this category from one function to another should be planned systematically.

Sub-Professional : The recruitment policy on technical assistants at present ("A" level graduates directly and "O" level graduates indirectly through selection among the Board employees) does not serve to maintain even basic educational standards, while technical entry requirements have been waived already. This category of staff at various levels will be the backbone to O and M supervision and management and therefore there is an urgent need to adopt a long-range policy on recruitment, career development and adequate training. A similar approach will be required for the Foreman category of staff as well.

Craftsmen : The ad hoc methods followed in the recruitment, selection and promotion of this category of staff should be rationalised with consideration to the need for acquisition of basic knowledge and skills in the trade. Hitherto, there was concentration of these staff mostly in the Central Workshop. A new policy of shifting the O and M responsibility to the periphery will mean that individual competence of these staff to perform tasks assumes greater importance.

Semi-skilled/Skilled : Continuous education and training is required to acquire knowledge and skills by this category of staff. Opportunities should also be provided to those having the potential to acquire supervisory skills. Non-formal education and self-study are avenues which should be open to promote the career prospects of these staff.

2.11 PRESENT TRAINING ARRANGEMENTS

2.11.1 Organisation Chart

Because of limited funds, the full recommendations of the July 1981 IRC/ITS Manpower Study have not yet been implemented. An interim training organisation has been set up. (See chart in **Appendix 6**). As the chart indicates, some positions have yet to be filled. The training staff have been given some training in instructional skills, but no-one has yet attended a full training programme covering the whole training function.

2.11.2 Maintenance Training

The number and range of courses on the 1982 programme is a considerable increase over previous years. In the past year, the Training Section has run courses on pump O and M, treatment plant O and M, and O and M for OICs. However, these courses have consisted mainly of illustrated lectures. In 1982, some practical demonstrations and practice periods have been built in.

2.11.3 Determining Training Needs

Estimates of training needs are based mainly on the apparent jobs of each group of employees selected as candidates for a course. The lack of job descriptions, and lack of first hand knowledge of some of the jobs by Training Section staff, often makes this difficult. Trainees who attend courses are mainly selected from new recruits. It is assumed that new employees in a particular job classification will all start out doing the same kind of work. However, in practice this is often not so.

2.11.4 Training Methods

Because of limited resources and instructional skills, the lecture is the method of instruction used in most cases. We are informed, however, that training aids and equipment for more practical instruction are presently being obtained.

2.11.5 Evaluation of Training

Written pre and post tests are usually given to measure effects of training. No formal "on-the-job" evaluation takes place.

2.11.6 The Use of Outside Training Facilities for Maintenance Training.

Outside Training : A group of mechanics employed at the main workshop is currently enrolled on a 3 month course of evening classes held at the Ceylon German Technical Institute in Moratuwa. An additional batch of mechanics and electricians will be attending the next course of evening classes to start in January 1983. There is also a possibility that the recently hired foremen trainees can obtain some training at the German Technical Institute.

The Board's mechanical and electrical engineers are sent to workshops recognised by the Sri Lanka Engineer's Charter Institute for a maximum period of 2 years, usually 12 to 15 months. The mechanical engineers can go to the Machinery and Equipment Departments, The Port Commission or the Railway Workshops. The electrical engineers can be sent to the Ceylon Electricity Board's Workshop. These engineers are supposed to gain practical experience from this "training", but no evaluation of what they learn takes place. They are required to remain at the Board for a period equal to double their learning, or pay for the training, but this rule is not strictly enforced.

PART 3 : RECOMMENDATIONS FOR ACTION

3.1 ORGANISATION, STAFFING AND RESPONSIBILITIES

3.1.1 Responsibility for Maintenance

The people who are responsible for the provision of a water supply service should be the people responsible for the maintenance of the plant and equipment needed to give that service. The Operator, the Officer in Charge and the Regional Manager should be held accountable for ensuring the plant and equipment under their control is properly run, maintained and repaired. There are three levels of maintenance and, as far as possible, maintenance tasks should be shifted towards level (a):

(a) operational maintenance (by operator)
(b) preventive maintenance (by mechanics/electricians).
(c) breakdown maintenance (by mechanics/electricians).

For this to happen there needs to be an appropriate maintenance organisation, with maintenance responsibilities and duties made clear at all levels, with appropriate systems and controls, and with staff properly trained, equipped and motivated.

3.1.2. From Senior Management down to Scheme Level

The recommended organisation and staffing for the proper management of maintenance is given in **Appendix 7.** Key features are as follows:

(a) Construction should be separated from maintenance at all levels. One senior manager (AGM, O and M) should be given overall charge of all operation and maintenance aspects in the Island.

(b) The Region should be seen as the basic unit within the O and M organisation. As far as possible it should be self sufficient.

(c) The Regional Manager should be given responsibility and authority to manage all aspects of operation and maintenance in his Region.

(d) The Regional Manager should be helped to learn that most of the problems in his Region are his problems and it is up to him to get them solved. The AGM (O and M) must actively discourage RMs from bringing their problems up to him and must continually seek to help RMs develop their self sufficiency.

(e) The main function of the AGM (O and M) should be to implement NWS&DB policy on operation and maintenance through the RMs, giving particular attention to quality, efficiency and cost effectiveness. He should have two senior engineers at Headquarters to assist him : a Chief Engineer (Maintenance) and a Chief Engineer (Operations).

(f) Each of these Chief Engineers may have one or more Engineers/EAs reporting to him. However, the principle of Regional self sufficiency and autonomy should be followed as far as possible. As time goes on, the aim should be to reduce the Headquarters engineering staff.

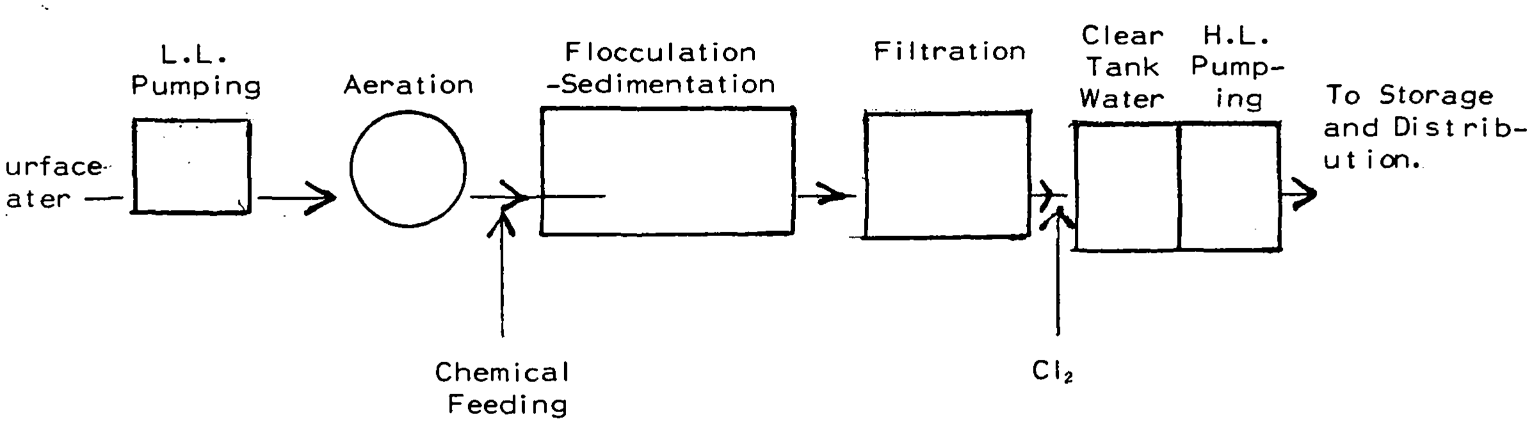
(g) There should be two Assistant RMs reporting to the Regional Manager, one responsible for maintenance and one for operations.

(h) Draft job descriptions for all the main jobs in the O and M organisation have been prepared and have been lodged with Ernst and Whinney.

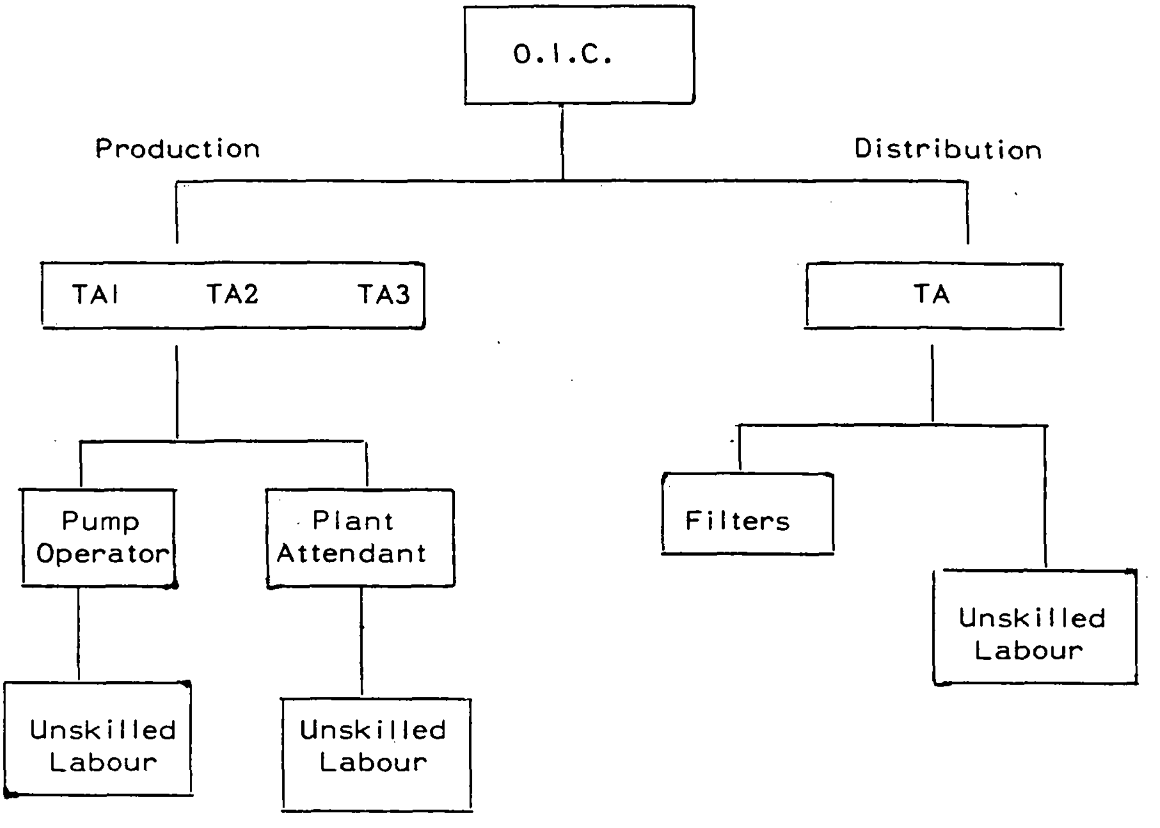
3.1.3 <u>Within Each Scheme</u>

Information on actually required staff numbers and organisation for each scheme is not held by NWS&DB and estimates could not be obtained during the time of the study. It is recommended that this information be determined as soon as possible. To assist with the task three "models" have been selected - a major urban scheme, a minor pumped scheme, a smaller gravity scheme and a recommended organisation chart and staffing given for each. This information can be used to guide decisions on staffing in each of the real schemes. Obviously, local pecularities and needs will incluence the final decisions for each.

(a) **A typical Major Scheme (urban)**



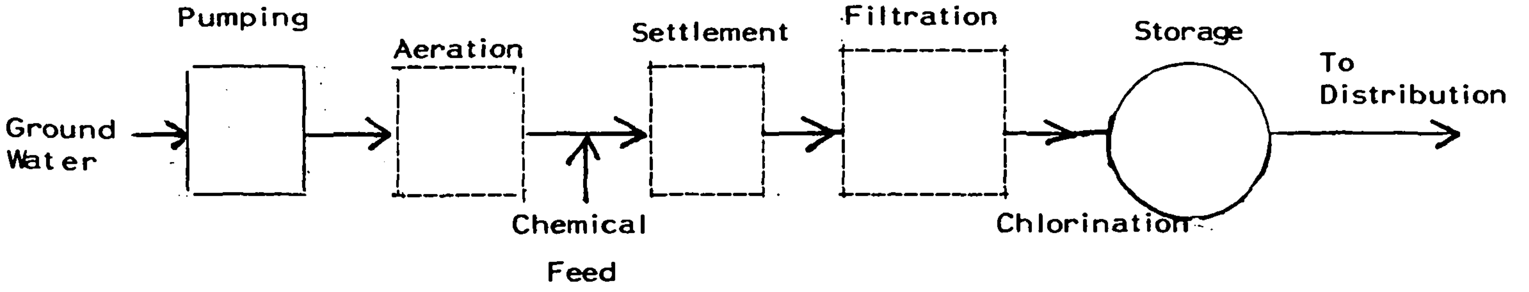
Galle water supply scheme represents all the above features of a major scheme. The organisation for management of the scheme may be divided into two parts viz, production and distribution of water.



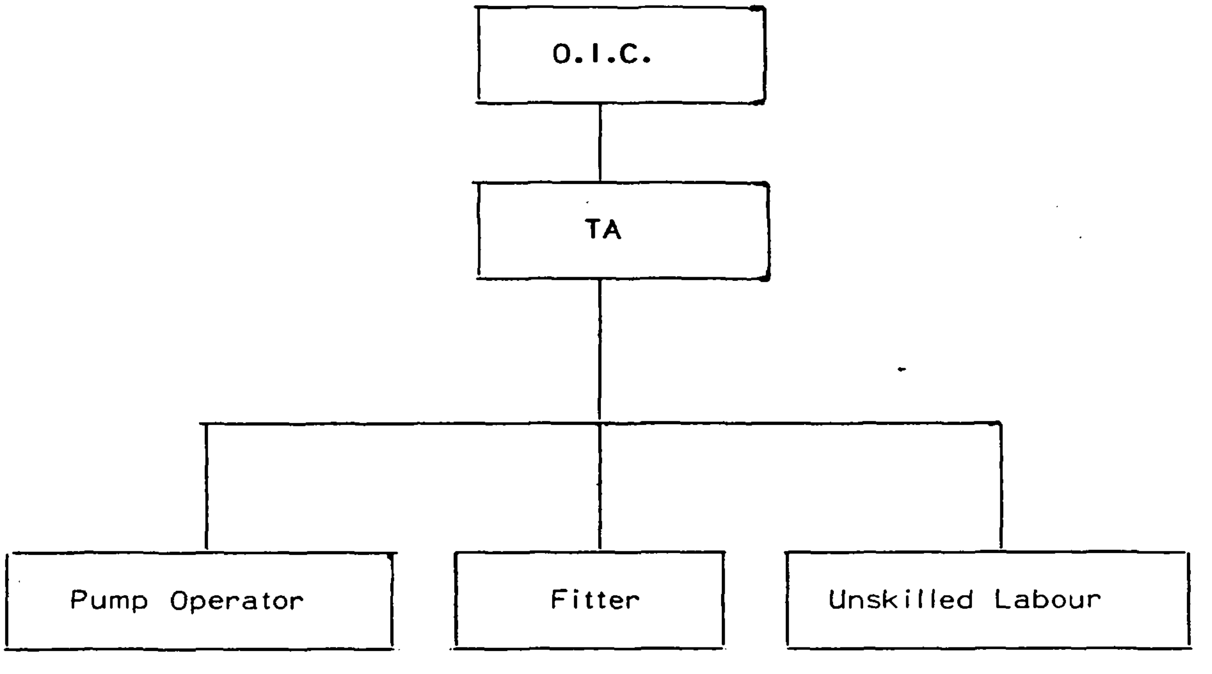
This is considered to be an appropriate organisation for Galle scheme. The current actual staff and the reequired staff (in brackets) are:

O.I.C.	-	I	(I)
TA's	-	4	(4)
Pump Operators	-	7	(7)
Fitters	-	6	(3)
Unskilled Labour	-	26	(10)
		44	25

(b) A Typical Minor Scheme (pumped)



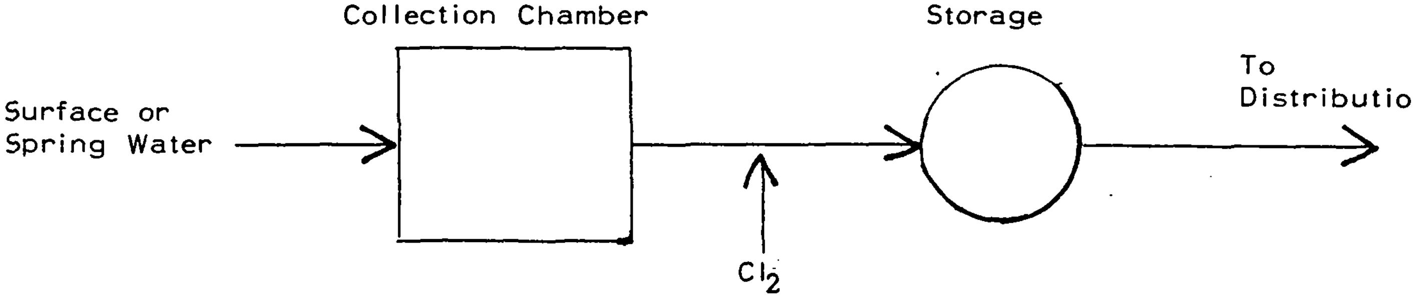
Treatment of water (shown dotted and optional) is exceptional in these cases. Generally, the scheme includes pumping of ground water, chlorination, storage and distribution. Staffing at these schemes varies with the size of the scheme and the distance between the headworks and the distribution system. The supervision and management of such schemes is handled by an OIC located at one scheme but in charge of one or more adjacent schemes. Typical staffing at such a scheme consists of:



For example, for Kataragama Water Supply Scheme, the actual, and also recommended numbers are:

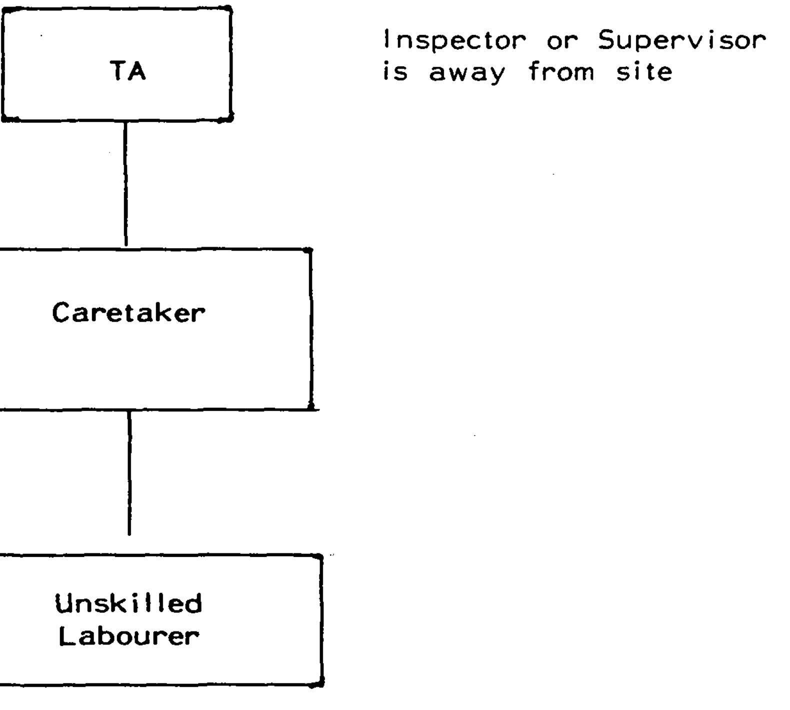
OIC ($\frac{1}{2}$), TA (1), Pump Operator (3) and Unskilled Labourer (7)

(c) A Typical Small Scheme (Gravity)



These schemes prevail in the upland areas. Surface water is protected and the only treatment required is chlorination.

The number of staff at this type of scheme is small. A caretaker with one or two unskilled labourers is all that is needed at site. Periodic supervision of course, is required in these cases.



For example, at Morawaka Water Supply Scheme, the actual, and also the recommended numbers are:

Caretaker (1) and Unskilled Labourer (1).

Points to emphasise regarding the management of <u>all</u> schemes, whatever their size, are as follows:

(a) Each operating scheme should be managed by an Officer in Charge. Very small schemes could be grouped together under one OIC. The important thing, however, is that each scheme in the Region should have someone of sufficient seniority, experience and ability to manage it.

(b) As with the RM, the OIC must be helped to learn that it is <u>his</u> task to solve most of the problems and <u>his</u> scheme. A major task of the ARM (Operations) should be to actively discourage problems at scheme level being referred up to him. He must continually seek to help OICs develop their ability at managing their schemes. Proper selection and training is vital.

(c) A major function of the OIC should be to ensure the ample manpower resources available to him are <u>used</u>. There are many tasks that could and should be done to improve the performance, efficiency, reliability and appearance of the plant. Such activity will also improve staff morale and commitment.

3.2 MAINTENANCE FACILITIES

3.2.1. The Regional Workshop

A Regional Workshop should be set up in the Galle Region, at or near one of the major schemes - preferably Galle or Matara. Its main role should be to carry out all the normal maintenance and repair work for the Region, apart from very specialised work such as motor rewinds and specialised machining. Major repairs to handpumps might become a future responsibiliy.

A recommended design is given in **Appendix 8.**

This is for a single storey building with 3 main workshop sections and two sub-sections partitioned from one another in such a way that the partitions can be easily moved to accommodate future developments. The recommended staffing for each section is as follows:

****

(a) Mechanical section	1 mechanic 1 mechanic/machinist
(b) Welding, blacksmithing oxyacetylene cutting and burning section.	1 mechanic/welder
(c) Electrical and Instrument repair section	1 electrician 1 instrument technician
(d) Meter repair section	1 meter repairman
(e) Carpentry section	1 carpenter

****

All staff should report to a General Foreman who should be responsible for the day to day operations of the workshop. A list of the main tools and equipment which should be in each section is given in **Appendix 9,** and approximate costs given.

The total cost of building and equipping this Regional Workshop is estimated as follows:

3024 sq.ft. at Rs. 150 per sq.ft.	454000
Construction site development at 20%	91000
Professional services (design supervision)	91000
Equipment and facilities (from Appendix 9)	909600
	Rs 1,545600 ($77300)

3.2.2 The Regional Stores

A Regional Stores should be set up close to the Regional Workshop. Its role should be to make available a balanced supply of chemicals, components, tools, equipment, maintenance materials, spare parts and any other commodities necessary to meet operational and maintenance requirements. It should be under the care of a Regional Storekeeper whose responsibilities should include ordering, inventory control, stock identification, safe custody and protection of stocks, receiving and issuing, documentation, liaison and assistance to storekeepers stationed at major schemes.

He should have a stores assistant to help him. The total cost of building the stores is estimated to be Rs.650,000 or $32500 (See **Appendix 10**).

3.2.3 The Mobile Maintenance Crew

The Mobile Maintenance Crew at Galle Region should be strengthened. It should be based close to the Regional Workshop. Its role should primarily be to implement the preventive maintenance programme for the Region. It should be composed of a working foreman, a mechanic and an electrician.

The preventive maintenance visits and routes should be planned so that two or four works are visited in one day (See Misra Report). Another duty of the crew should be to take damaged equipment back to the Regional Workshop for repair.

The crew should have a small but rugged vehicle to enable it to travel quickly and easily to all locations. A long wheelbase Landrover is suggested. The vehicle should carry a toolbox containing the following:

Spanners, pipe grips, hammer, general mechanics tools.

Electrical measuring instruments, electricians tools.

A set of lifting tackle of 1 ton capacity.

A selection of spare parts.

Estimated costs are as follows:

Long Wheelbase Landrover		420,000	
Mechanic's tools		14,000	
Electrician's tools		14,000	
Portable flowmeter, pressure gauge and test equipment		24,500	
Lifting Tackle		10,500	
	Rs	483,000	($24,000)

3.2.4 Maintenance Staff at Individual Schemes

One mechanic and one electrician should be assigned to each of the four major schemes in the Region (Galle, Matara, Tangalle, Hambantota) to assist the operators to cope with the day to day maintenance problems there.

3.3 SYSTEMS AND PROCEDURES

3.3.1 Preventive Maintenance

As part of the study, we have obtained manufacturers' leaflets and booklets for many of the pumps, motors, chlorinators and various minor mechanical and electrical items in use by NWS&DB. Many of these give full descriptions, drawings, lists of spares, and recommended maintenance schedules and recording sheets. An example for a centrifugal pump is given in **Appendix 11.** We have also supplied examples **(Appendix 12)** of typical documentation used in the implementation and control of preventive maintenance programmes. One of these shows a page from a set of instructions given to a Chargehand listing the maintenance work he must do and the reports he must write. All this information has been given to the WHO Technical Officer on Maintenance, and it should form a sound basis for the development of a preventive maintenance programme within NWS&DB.

3.3.2 Planning and Design Decisions

Recommendations on planning and design are outside the scope of this study. Suffice to say that many maintenance problems are built in at the early planning and design stages and unless proper technical appraisals are made at this time, serious maintenance problems will continue to be created.

3.3.3 Installation and Commissioning of Plant and Equipment

It is recommended that NWS&DB insists on a proper contract being drawn up with suppliers and installers which will spell out and ensure:

- adequate staff training in how to operate and maintain the equipment;
- comprehensive reference manuals on operation and maintenance;
- correct sets of all the tools needed;
- a sufficient supply of spares and the promise of speedy follow up service needed.

3.4 MANPOWER PLANNING, RECRUITMENT AND SELECTION

3.4.1 Manpower Recording, Forecasting and Planning

Getting accurate information on actual numbers of staff on operation and maintenance proved difficult. One reason is that some of the staff employed on providing new service connections and some of the staff on construction work are grouped under O and M. Estimates of the future manpower requirements for operation and maintenance could not be obtained during the course of the study. NWS&DB cannot possibly ensure that it always has sufficient numbers of properly trained manpower to do the tasks required unless it recruits and trains adequate numbers of people each year. And it cannot do this unless it knows the numbers and calibre of the people it employs now and has made reasonably accurate estimates of its future needs, and also its future supply.

Manpower information for the whole Sector was given in the July 1981 IRC/WHO/ITS Report. These figures could be used as a start for determining the specific O and M manpower requirements for Galle Region. More importantly, however, the Report illustrates in detail how to produce a manpower plan. It is recommended that a detailed manpower plan be developed for O and M, using this Report as a guide.

3.4.2 Recruitment and Selection Policies

The recruitment and selection of EAs/TAs and also Craftsmen should be given particular attention. At present, the standard of many recruits is low - yet these will be the key people in the new decentralised O and M organisation. It is recommended that the job descriptions, when agreed, should be used as bases for determining minimum standards of recruitment. Selection methods should be improved, to ensure only those who met these standards are taken on.

3.5 STAFF MANAGEMENT AND ATTITUDES

Improved maintenance performance at a scheme will only occur if employees at that scheme change their behaviour and actually do what is necessary. This will only occur if they have a pride in their scheme and really want it to be clean, efficient and correctly maintained. Some of the things it is recommended should be done to bring about this set of attitudes:

(a) Regular inspection visits by Regional and Headquarters management to each scheme to communicate and insist upon the standards required and to commend those who achieve them.

(b) More consultation, involvement and discussion between operations/maintenance staff and management on problems and needs of mutual concern. Managers at all levels to get out far more and talk to people at the schemes.

(c) A quicker and better "support service" from HQ to provide staff at scheme level with information, help, tools, spares, etc., when needed. The lack of this at the moment, is a major demotivating factor.

(d) An annual "best kept scheme" competition in the Region, with prizes for all staff at the winning scheme. Judging by a Senior Manager and/or a local dignatory.

(e) Run "open days" at schemes when the public can visit, inspect and ask questions about how their water supply is provided.

(f) Provide educational visits for groups from local schools, hospitals, youth clubs, etc.

(g) Put some of the more picturesquely sited schemes on the tourist map and encourage tourists to visit on a certain day each week.

(h) Increase public awareness about NWS&DB by telling them what is going on. Use any interesting developments as excuses for a slot on T.V. The T.V. companies are most willing to give publicity to these. Increased awareness will lead to a more educated public and more local pressure for a proper water supply service to a standard it has a right to expect. Encourage members of the public to complain to their local scheme (not write to the Chairman) when they are dissatisfied. Let them call in and talk to the Officer in Charge.

3.6 A MAINTENANCE TRAINING PLAN

3.6.1 Develop the Training Section

A training plan for NWS&DB was proposed in the previous IRC/WHO/ITS study (July 1981). This training plan was designed to meet the total training needs of the sector over the five year period 1981 - 1986. Since that study, progress has been made with enlarging the Training Section. This present study has confirmed that (at least as far as maintenance is concerned) the training recommendations made in that earlier plan are still valid. The Training Section should therefore continue to be developed along the lines of the Manpower Unit recommended in Section 12.4 of that study report. A new development however, is the community wells and handpumps programme in rural areas, which requires Training at the community level, the District level and the Regional level as the institutional arrangements are established. The minimum that should be done is outlined in the Sections which follow.

3.6.2 Take Action to Start Maintenance Training Now

The present study has confirmed that maintenance training remains a top priority in the overall training plan. It is recommended that action is begun now along the lines given below.

3.6.3 Set up a Maintenance Training Centre

A Training Centre should be designed and equipped along the lines of that in the IRC/WHO/ITS 1981 report. As there may be delays in funding for this, it is recommended that an interim centre for practical training be set up as soon as possible. It is believed that an area approximately 30ft x 50ft may be available for this in the present Central Workshop. A recommended design is shown in **Appendix 13.** It has four training sections designed to accommodate the following numbers of trainees at any one time:

mechanical section	-	8 trainees
electrical section	-	8 trainees
instrument section	-	2 trainees
welding section	-	2 trainees

It will require approximately 180 feet of partitioning to separate it from the Central Workshop and to divide it internally. The cost of suitable partitioning including erection is likely to be around Rs 1220 per foot run. Lists of tools, equipment, facilities, etc., that should be provided in each section are given in **Appendix 14,** and approximate costs given. The total cost of building and equipping this interim Maintenance Training Workshop, within the Central Workshop, will therefore be approximately as follows:

Partitioning 180ft. at Rs 1220 per ft. run :	219,000
Equipment and Facilities for	
Mechanical Section :	380,000
Electrical Section:	215,000
Instrument Section :	211,000
Welding Section :	72,000
Office :	Rs 1, 097,000
	($54,000)

3.6.4 Appoint Instructors for the Maintenance Training Workshop

Four instructors should be appointed as follows:

One mechanical instructor : primarily to train new and existing mechanics, but also to give basic training to OICs, Shift TAs, electricians and pump operators.

One electrical instructor : primarily to train new and existing electricians, but also to give basic training to OICs,. Shift TAs, electricians and mechanics.

One welding instructor (part-time) : primarily to train new and existing welders but also to give basic training to mechanics.

The appointment of these instructors should be phased in with the development of the Maintenance Training Workshop. A recommended timetable is as follows:

Immediately the Training Plan is approved:

(a) appoint the mechanical and electrical instructor - to help with the development and installation of the training facilities and materials needed, and to ensure their (very urgent) training programmes are ready as soon as possible.

(b) appoint the instrument instructor - initially to study the flowmeter material that has been provided with this study and develop training programmes on flowmeter maintenance and repair; later to assist in the equipping of the instrument section of the Maintenance Training Workshop and with developing instrumentation training programmes.

Six months later:

(a) appoint the part-time welding instructor -

At the beginning the instructors should report to the Head of Training. Later (say when the welding instructor is appointed) it is recommended that one of the instructors be promoted to Chief Instructor, and an additional instructor recruited to replace him. The Training Workshop workload should justify this promotion at about that time. The Chief Instructor's main duties should include:

- day to day management of the Training Workshop.
- scheduling courses.
- setting and maintaining standards of instruction.
- developing and improving Training Workshop practices.
- maintaining records.

3.6.5 <u>Training the Key Staff in the Training Section</u>

A programme for training the Manpower Unit staff was given in Section 12.7 of the July 1981 IRC/WHO/ITS Report. If funds preclude all this, it is recommended that the following steps be taken, as a minimum. These are necessary to ensure that maintenance training needs are met - but of course will help ensure that other training needs are met also.

(a) Engage a visiting consultant to work with a Senior Trainer and his staff in the Training Section to help them get the whole maintenance training programme off the ground. In helping them achieve this, he should ensure the whole team develops a thorough understanding of all the main stages in the maintenance training process - identifying needs, designing training, running training programmes, reviewing and evaluating the effects. Clearly this understanding will help them tackle other areas of training too. It is recommended that this assistance should be in 3 periods of 8 weeks spread over a year.

(b) During the year, (ideally between the first and second 8 weeks periods), send a Senior Trainer from the Training Section overseas to attend a modular training programme designed especially for overseas Trainers. Such a programme should consist of about 20 working days of formal tuition off-the-job and about 40 working days of project work in water undertakings and in training centres catering for the needs of water supply.

(c) Train the Workshop instructors in the skills of designing and giving practical and classroom instruction. This should be given by the WHO Technical Officer on Training, assisted by the visiting consultant in (a) above.

3.6.6 Provide Consultancy Help for NWS&DB on O and M Management

The most important person in the whole strategy for improving maintenance performance across NWS&DB is probably Mr. Parameswaram - the AGM (O and M). He has a large and very difficult task to perform. It is strongly recommended that a visiting consultant be engaged for a period of 6 months to work alongside him. The consultant's main function would be to develop Mr. Parameswaram's management skills and his understanding of the job that is required of him, help him introduce the new maintenance organisation and help him develop the abilities of his eight Regional Managers. He should also spend time working with managers above and below the AGM (O and M) to ensure the new maintenance organisation is effectively introduced and operated at all levels.

The consultant should have experience of successfully managing the operation and maintenance of water undertakings which have variety of urban and rural schemes, of introducing major organisational change, and of developing management staff - especially through coaching. Some of this experience should have been in a developing country. This O and M management support would complement the technical support to maintenance already being provided by W.H.O.

3.6.7 Help the Regional Manager to Implement the New Organisation in his Region.

The Galle Regional Manager also has a large and difficult task. Previously he spent most of his time on construction aspects. This report points out that in future he should spend all of his time on operation and maintenance aspects. It proposes organisational changes within the Region and also that the RM should build it up to be as self sufficient as possible. It is therefore recommended (as indicated in 3.6.6) that another main function of the consultant on O and M management should be to help the Galle Regional Manager (and the other Regional Managers if and when appropriate) to introduce the organisational changes in his Region. He should be assisted in this by a Senior Trainer and the visiting training consultant.

3.6.8 Complete the Process of Clarifying Jobs and Writing Job Descriptions

Another urgent task is to complete the process of clarifying the major responsibilities and duties, and producing a job description, for each job holder in the new Operation and Maintenance organisation. Some work has already been done by Ernst and Whinney, and some more in this present study. A member of the training staff, with guidance from the visiting training consultant, should now do the following:

(a) Compare all the job descriptions with each other and with the organisation chart. Identify and correct any major inconsistencies, errors or ommissions.

(b) Starting with the AGM (O and M) and working downwards through the organisation, discuss each job description with the job holder, then with his immediate superior, and finally with both together. It may also be necessary to discuss certain aspects with his subordinates and with colleagues at the same level. The purpose of all this is threefold:

- to produce an agreed description of what the job holder's main responsibilities and duties ought to be, in the interests of the organisation.
- to give clarity and understanding of this in the mind of the job holder.
- to produce a written record of what has been agreed.

Using these job descriptions as a basis, a set of training programmes can be prepared for new and existing job holders. These have still to be developed in detail, but some guidelines for the remaining priority training categories are given below in Sections 3.6.9 - 3.6.11.

3.6.9 Design Training Programmes to Develop the Technical and Supervisory Skills of the O.I.C.s.

It is recommended that the current O and M course for OICs should be developed into two separate courses:

(a) a combined theory and practical course on operations and maintenance. The practical work should include spells in the mechanical, electrical and instrument sections of the Training Workshop.

(b) a classroom based course on techniques of supervision, with follow-up back on the job. The visiting training consultant should help develop and run the first of these courses.

3.6.10 Design a Training Programme on Flowmeter Maintenance and Repair

This is needed urgently. Much of the metering equipment at the major schemes is out of action and plant efficiency cannot be optimised.

The instrument instructor, using the reference material provided with this study, should develop a practical programme for training instrument technicians on flowmeter maintenance and repair. The Training Section should help him design the programme. It should probably last 5 days in the Training Workshop plus a short time at selected sites under construction to observe the installation of new equipment. It should be used to train one electrician to become the instrument technician for the Galle Regional Workshop (and probably one from each of the other Regions as well). This could form a foundation programme for the full training of instrument mechanics later.

3.6.11 Design Training Programmes for Mechanics and Electricians

Further study is needed of the skills required and available to determine precisely what should be included in these training programmes.

One of the first tasks for the mechanical and electrical instructors should be to identify what is required and then to design these programmes. Some guidelines to help them are as follows:
Training for mechanics should be largely practical and should include instruction in the use and care of tools, stripping and reassembling of pumps and other equipment, bench fitting, fault diagnosis, pump testing, drilling, shaping, bench grinding, safety, basic electrics.

Training for <u>electricians</u> should also be largely practical and should include instruction in the use and care of tools, wiring of switches, plugs, sockets and the various switchgear associated with pumping equipment, fault diagnosis, safety, basic mechanics. The required duration of these programmes is not yet known. The suggestions given in July 1981 IRC/WHO/ITS Report give an approximation:

<u>Newly Appointed</u>:

Ten weeks in the Maintenance Training Centre (4 days practice, 1 day classroom per week) to develop the basic skills and knowledge of the trade.

Six months on-the-job supervised practice to apply the skills in a variety of situations.

Ten more weeks in the Maintenance Training Centre and classroom to reinforce their basic skills and develop advanced skills.

<u>Existing</u>

Four weeks in the Maintenance Training Centre and classroom to develop a better understanding of their responsibilities and to develop and strengthen the practical job skills that are needed.

Planned on-the-job coaching and assignments to help and encourage the better people to stay and advance to supervisory positions.

3.6.12 <u>Develop a Career Structure which Opens Up Prospects for All Staff to be Promoted</u>

The survey has noted a number of instances of "blockages" where good people cannot be promoted because of the lack of some qualifications. This has led to demotivation and the loss of good staff.

The development of a career structure for NWS&DB is too large a task for this present study, but the need for one has been clearly identified. A detailed analysis of current promotion routes has been made by the WHO Technical Officer on Training, and this work should be continued urgently.

3.7 EXTENDING THE APPROACH TO OTHER REGIONS

One of the study's Terms of Reference has been to help NWS&DB make a generalised application of the approach. The involvement of WHO Resident Staff throughout the study, and the involvement of Senior Managers, Trainers and Engineers at frequent intervals, should already have developed a bank of expertise which can extend the study.

It is recommended that NWS&DB, with the assistance now available from WHO, World Bank, etc., should now organise and manage the extension of the approach across two more Regions. This extension of the present study should aim to answer the following questions:

(a) Are the maintenance deficiencies in these other Regions the same as the Galle Region?

(b) Are the reasons for these deficiencies, and the reasons why they still persist in spite of previous studies, the same as Galle Region?

(c) What practical action can be taken to improve the situation?

Almost certainly the answers to questions (a) and (b) will be "yes". And very likely the answer to question (c) will be "very similar to Galle". The important thing, however, is the <u>thinking through</u> of the problems and solutions by managers, engineers and staff at HQ and in the Regions. The purpose of the suggested study, therefore, is not so much to answer the questions, but instead to <u>stimulate</u> management and staff at all levels to face up to the problems, think through their causes and arrive at practical solutions which they are prepared to act upon.

3.8 ACTION

The aim of this Report has been to continue the process of bringing about practical action to improve maintenance performance. It includes recommendations for a limited degree of outside help to assist with certain parts of this action. But apart from this, NWS&DB has all it needs to make big improvements now in many areas of maintenance. It does not need more studies, more data, more reports, more resources, more systems, to do this. All it needs is the will to do it.

This "will" can only come if people - either in NWS&DB, the Ministry of the community - are dissatisfied with the way things are now.

When comparing "what it is" with "what it was", or even "what it is here" with "what it is in some other countries" - there is cause for great satisfaction.

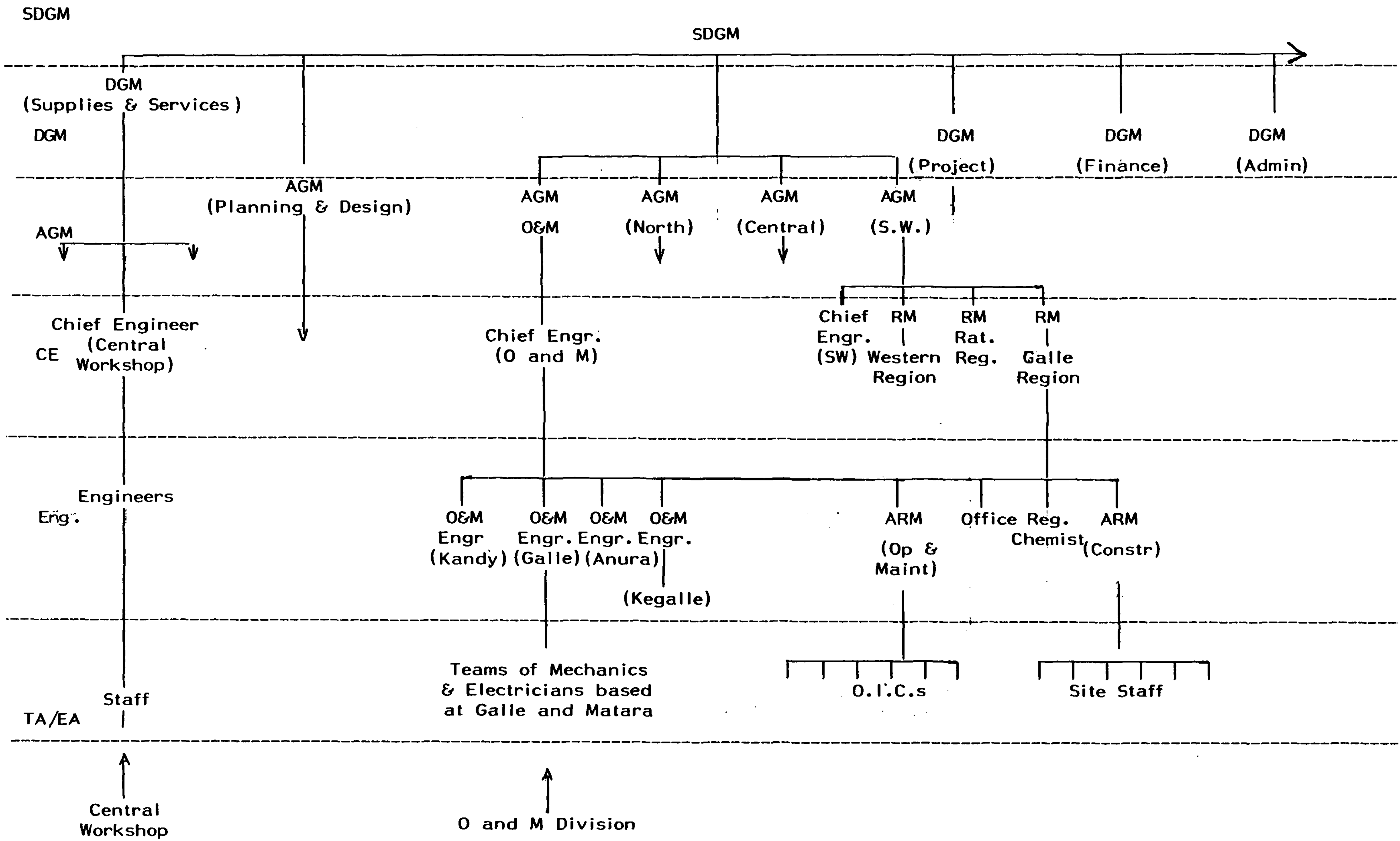
But the real comparison to make is between "what it is" and "what it could be". Our study has revealed a glimpse of what it could be - that greater efficiency and better service to the community are possible. We believe the Ministry, and community and NWS&DB itself should be dissatisfied until this is achieved through practical action.

APPENDICES

1 Organisation chart for operations and maintenance at the start of the study.
2 Water Supply Schemes - Galle Region
3 Summary of schemes in operation and under construction, with staffing - Galle Region.
4 Description of plant and equipment in each scheme - Galle Region.
5 Breakdown maintenance tasks, May-July 1982.
6 Organisation chart - training section.
7 Proposed organisation chart for operations and maintenance at HQ and in Galle Region
8 Sketch plan of proposed Regional Workshop and Stores.
9 Regional Workshop - list of tools and equipment needed, with estimates.
10 Regional Stores - building cost estimates.
11 Example manufacturers instruction manual (centrifugal pump).
12 Example of planned maintenance documentation.
13 Sketch plan of proposed Maintenance Training Centre.
14 Maintenance Training Centre - list of tools and equipment needed, with estimated costs.

APPENDIX I

Present Organisation Chart for Operation and Maintenance



APPENDIX 2

Water Supply Schemes - Galle Region

1. MAJOR SCHEMES (MUNICIPAL)

Galle
Matara
Ambalantota - Hambantota
Tangalle
Weligama

2. MINOR SCHEMES (RURAL-PUMPED)

a) **Population 5001 - 10000**

Akuressa
Kataragama
Deniyaya

b) **Population 3001 - 5000**

Bogalapelessa
Beliatta
Ranna
Tissamaharagama

c) **Population 1501 - 3000**

Baddegama
Kamburupitya
Walasmulla
Middeniya
Yodakandiya
Ridiyagama
Weerakatiya
Hikkaduwa - Dodanduwa
Hungama
Petigala
Hakmana
Kudawella

3. SMALL SCHEMES (RURAL-GRAVITY)

Morawaka
Nakiyadeniya
Kirama

APPENDIX 3

Summary of Schemes in Operation &
Under Construction - Galle Region
(with staffing)

WATER SUPPLY SCHEMES - GALLE REGION

Major Schemes (Urban)

	Head Works and Distribution by NWS&DB	Head Works By NWS&DB Distribution LA	Head Works and Distribution by L.A.	Actual Staff								Required Staff							
				OIC	TA	Elect.	Mech.	Pump Op.	Plant Attn.	Fitters	Unskilled	OIC	TA	Elect.	Mech.	Pump Op.	Plant Att.	Fitters	Unskilled
1. Galle	✓			1	3			7		6	26								
2. Matara		✓		1	2			17		2	17								
3. Ambalantota-Hambantota		✓		1	3			4		3	14								
4. Tangalle	✓				2			4		2	8								
5. Weligama	✓			1	1			3			7								

Appendix 3 (continued)

WATER SUPPLY SCHEMES - GALLE REGION

Minor Schemes - (Rural Pumped)

	Head Works and Dist. By L.A.	Head Works By NWS&DB Dist. by L.A.	Head Works By NWS&DB Dist. by LA	Actual Staff				Required Staff			
				OIC	Caretaker	Pump Op.	Unskilled	OIC	Caretaker	Pump Op.	Unskilled
(Population 50001 - 10,000)											
1. Akuressa			✓		1 Over Fitter	3	1 Fitter				
2. Kataragama	✓			½	1 (TA)	3	7				
3. Deniyaya			✓		11 Over seer	1 Fitter	1				
(Population 3001 - 5000)											
4. Bogalapelessa	✓			½ @ Kambur-upitya		10	2				
5. Beliatta			✓			2					
6. Ranna	✓				1 Fitter	1	2				
7. Tissamaharagama			✓								
(Population 1500 - 3000)											
8. Walasmulla	✓			1		1	1				
9. Baddegama	✓		✓	½ @ Galle		1	2				
10, Middeniya			✓								
11. Kamburupitya					1 Water Supply Assistant		1				
12. Yodakandiya	✓		✓				2				
13. Weerakatiya						2	1				
14. Hikkaduwa-Dodanduwa	✓			½ @ Galle		3	10				
15. Hungama	✓			1		3	5				
16. Ridiyagama	✓					2	2				
17. Petigala)Under 18. Hakmana)Constr- 19. Kudawella)uction.											

Appendix 3 (continued)

WATER SUPPLY SCHEMES - GALLE REGION Small Schemes - (Gravity Rural)									
	Head Works and Dist. By NWS&DB	Head Works By NWS&DB Dist. by LA	Head Works and Dist. by LA	Actual Staff			Required Staff		
				OIC	Linesman	Unskilled	OIC	Field Att.	Unskilled
1. Morawaka					1	1			
2. Nakiyadeniya					N.A.				
3. Kirama				OIC @ Hakman		3 (2 watchers)			

Description of Plant and Equipment in Each Scheme, Galle Region

G A L L E

EQUIPMENT	TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
1. Low Lift Station				
1.1 Pump No.1	Vert. Turbine (Sigmund Pulsometer)	O.K.	No. Strainers. Broken non-reverse ratchets.	No strainers, causing frequent clogging of impellers. New strainers being fabricated. Ratchets have been ordered
No.2	"	"	"	"
No.3	"	"	"	"
No.4	"	"	"	"
Motor No.1	Crompton-Parkinson Wound Rotor Induction.	O.K		Brushes need frequent replacing
No.2	"	"	Bearings replaced	"
No.3	"	"		"
No.4	"			"
1.2 Starters	Allen-West	"		Only 1 Voltmeter Selector Switch not operating.
1.3 Sumplow level Sensor		Not O.K.	Never in operation	This unit provides low water level signal to chemical room.
1.4 Pressure Gauges				None
1.5 Flow-meter	Kent			Rate of flow indicator in working order. Probably needs re-calibration No supplies of indicator charts, special lubrication grease. Total flow recorder does not provide accurate reading.
2. High-Lift Station				
1.1 High Lift Pump No.1	Horiz. split, double suction (Sigmund Pulsometer)	O.K.)	1 or 2 impellers replaced in the past.	
No.2	"	) "		
No.3	"	) "		
No.4	"	) "		

EQUIPMENT	TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
High Lift Motor No.1	Wound rotor induct-tion Mather & Platt	O.K.	) Slip rings filled and machin-) ed.	
No.2	"	"	) Carbon brushes need frequent	
No.3	"	"	) replacement	
No.4	"	"	)	
2.2 Starters (high lift)	Allen-West	O.K.		
2.3 Flow-Meter	Kent	Not O.K.		Parts missing
2.4 Pressure Gauge (high lift)		Not O.K.		Need overhaul and calibration. Damage caused by water hammer.
2.5 Backwash Pumps	Mather & Platt	O.K.		
No.1	Horiz. split. Double Action	"		
No.2	"	"		
Backwash Motor				
No.1	Wound Rotor Induct-ion.	"		
No.2	Mather and Platt	"		
No.3	"	"		
2.6 Starters(Backwash)	Allen West	"	Main coil on one starter replaced	
2.7 Flow Meter (Back-wash)	Kent	Not O.K.		Not in operation for many years
2.8 Filter Blowers	Hammond (?)	O.K.		
No.1		O.K.		
No.2		Not O.K.		Not in operation for over 2 years.Parts missing in lubrication line. These have been ordered.
Blower Motors				
No.1		O.K.		
No.2		Not O.K.		Not in opeoation for many yeans.
2.9 Compressors No.1		O.K.		
No.2		Not O.K.		Pressure switch inoperative

APPENDIX	TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
3. Chemical Dosing Room				
3.1 Ferric Chloride Pumps	Reciprocating. Wallace & Tiernan			
No.1		O.K.	Replaced Plunger Shaft	Dosage cannot be adjusted. Plastic Wheels need replacing
No.2		"		"

EQUIPMENT		TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
Ferric Chloride Motors					
	No.1	Squirrel Cage Induction	O.K.		
	No.2	"	"		
Ferric Chloride Starters	No.1	Ottermill	"		
	No.2	"	"		
3.2 Lime Pumps	No.1	Wallace & Tiernan	O.K.		
	No.2	"	"		
	No.3	"	"		
	No.4	"	"		
Motors (Lime Pumps)	No.1		O.K.		
	No.2		"		
	No.3		"		
	No.4				
Starters (Lime	No.1		O.K.		
	No.2		"		
	No.3		"		
	No.4		"		
3.3 Lime Stirrers					
Motors	No.1	SQ. Cage Induction	O.K.	Keys replaced on Nos. 1,2. Oil seals replaced on all	
	No.2		"		
	No.3		"		
Starters (Stirrer Motors)		Ottermill	O.K.		
4. Clarifier					
4.1 Flocculator Motors					
	No.1		O.K.		) Drive Belts Need Frequent Replacing
	No.2		"		)
			"		)
Starters (Floc Motors)			O.K.	Have given trouble in past.	

EQUIPMENT	TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
4.2 Sludge Scraper Motor	S.Q. Cage Induction	O.K. "	Ratchet wheel of reduction gear replaced. Slip ring for supply cable replaced.	
4.2 Chlorinators No.1 No.2 No.3 No.4	) Wallace & Tiernan)))	O.K.		Only 2 being used for post chlorin-ation.
			M A T A R A	
1. Low Lift Station (Nadugala)				
1.1 Low Lift Pump No.1 No.2 No.3	Vert Turbine " "	O.K. "		
Pump Motors (low lift) No.1 No.2 No.3		O.K. " "		
Starters (low lift pumps) No.1 No.2 No.3		O.K. " "		
1.2 Flow Meter (low lift)	Kent		Recently repaired by Paterson Candy. Not calibrated.	
2. High Lift Station (Nadugala)				
2.1 High Lift Pump No.1 No.2 No.3 No.4		O.K. " " "		Nos. 1 and 2 are old pumps, Nos. 3 and 4 are new pumps with higher capacity.
High Lift Motors No.1 No.2 No.3 No.4		O.K. "		

EQUIPMENT	TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
High Lift Starters No.1		O.K.		2 New starters and 2 old starters
No.2		"		
No.3		"		
No.4		"		
2.2 Flow-Meter (High-lift)	Kent	Not O.K.		Being repaired by contractors
2.3 Pressure Gauges(4)		O.K.		4 new gauges for pumps Nos. 3 and 4.
2.4 Backwash Pumps No.1		O.K.		
No.2		"		
No.3				
Backwash Motors No.1		O.K.		
No.2		"		
Starters (Backwash) No.1		O.K.		
No.2		"		
2.5 Pressure Gauge (Backwash)		Not O.K.		Needs calibration. Pressure gauge located on common discharge.
2.6 Flowmeter (Back-wash)	Kent	Not O.K.		Being repaired
2.7 Generators (3)	Skoda	Only 1 Engine working		Problems with spares
3. <u>Chemical Room</u>				
3.1 Alum and Lime Pumps				New pumps installed but not commissioned
4. <u>Chlorinators</u> (2)	Wallace & Tiernan	O.K.		Recently installed
5. <u>Booster Pumps</u> (Peekwella) No.1		"		
No.2		"		

EQUIPMENT	TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
Booster No.1 Motors No.2		O.K. "	Carbon brushes need frequent replacement	
Starters No.1 (Booster No.2 Pumps)		O.K. "		
6. Booster Station (Nupe)				
6.1 Booster No.1 Pump No.2		O.K. "	Pump/motor coupling problems "	
Booster No.1 Motor No.2		O.K. "		
Starters (Booster)		O.K.		
		AMBALANTOTO (Old Scheme)		
1. Low Lift Station				
1.1 Low Lift No.1 Pumps No.2 No.3	End Suction " "	O.K. " "		) Over 30 years in operation.) No major repairs over past 3 years. Temporary Pump
Motor (low No.1 lift) No.2 No.3		O.K. " "		
Starters (low lift)	MEM (Star Delta)	O.K.	Starter contacts replaced	
1.2 Pressure Gauges (4)				Require calibration
2. High Lift Station				
2.1 High Lift No.1 No.2 No.3 No.4	End Suction " " -Engine Drive "	O.K. " " "		

EQUIPMENT	TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
Motors (high lift) No.1 No.2 No.3				) Motors 1&2 Overheating)
Starters (high lift) No.1 No.2		O.K. "		No starter for motor No.4. Contacts on starters 1&2 to be replaced.
2.2 Pressure Gauges (4 gauges on Pumps 1&2)				Requires calibration
2.3 Generator				Very old. Problems with spares.
3. Clarifier				
3.1 Flocculator Motor		Not O.K.		Not in operation for years.
4. Chemical Room				
4.1 Blower (Filter B/Wash)		O.K.		
Blower Motor		O.K.		
4.2 Chlorinator	Wallace & Tiernan	O.K.		
			TANGALLE	
1. Low Lift Station				
1.1 Low Lift Pumps No.1 No.2 No.3 No.4		O.K. " " "		
Motors No.1 No.2 No.3 No.4		O.K.		

EQUIPMENT	TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
Starters (Low lift) No.1	MEM	Not O.K.		Contacts to be replaced
No.2	"	"		"
No.3	Brook	O.K.		
No.4	"	"		
1.2 Pressure Gauges (4)				4 Gauges on Pumps 1&2 require calibration
2. High Lift Station				
2.1 High Lift Pumps No.1		O.K.		) Pump and motor bearings for 1
No.2		"		) pump need to be replaced.
Motors No.1		O.K.		)
No.2		"		)
Starters No.1		O.K.		) Contacts getting burnt frequently
No.2		"		)
2.2 Pressure Gauges (4)				Need calibrating
3. Chemical Room				
3.1 Blower		O.K.		
Blower Motor		O.K.		
3.2 Chlorinators No.1	C.E.	Not O.K.		Needs spares
No.2	Wallace & Tiernan	O.K.		

EQUIPMENT		TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
			W E L I G A M A		
1. Low Lift Station					
Low Lift Pumps	No.1		O.K.		
	No.2		"		
	No.3		"		
Motors (low lift)	No.1		O.K.		
	No.2		"		
	No.3		"		
Starters (low lift)	No.1				Spares not available for this make of starter. 100 Amp cartridge fuses not available.
	No.2				
	No.3				
2. Chlorinator		C.E.	O.K.		
			B A D D E G A M A		
1. Low Lift Station					
Low Lift Pump	No.1		O.K.		
	No.2		Not O.K.		Bent shaft. Draws high current.
Motor (low lift).	No.1		O.K.	Both motors replaced recently	Motor burn-outs probably caused by under voltage condition.
	No.2		"		
Starters (Low lift)	No.1	Furnes	O.K.		Over current protection not sufficiently sensitive.
	No.2	"	O.K.		

EQUIPMENT	TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
		WALASMULLA		
1. Low Lift Station				
1.1 Pumps (Low No.1 lift) No.2		O.K. "		
Motors (low No.1 lift) No.2		O.K. "		
Starters No.1 (low lift) No.2		O.K. "		
1.2 Backwash No.1 Pumps		O.K.		
Motor No.1		"		
Starter No.1		Not O.K.		Recent repair at w/shop unsatisfactory problem with o/l relay.
		KATARAGAMA		
1. Low Lift Station				
Pumps No.1 No.2	Submersible	O.K. "		
Standby Pum	Engine Driven	O.K.		
Starters			Recently repaired	
2. Chlorinators No.1	Advance			Chlorination done in well.

EQUIPMENT		TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
			TISSA-KATARAGAMA		
1. Low Lift Station					
Low Lift Pumps	No.1	Mono	O.K.		
	No.2	"	"		
	No.3	"	"		
Starters (3)			O.K.		
			YODAKANDIYA		
1. Low Lift Station					
Pump	No.1	Engine Driven	O.K.		
			RIDIYAGAMA		
1. Low Lift Station					
Pumps	No.1	Ceygma	O.K.		
	No.2		O.K.	Bearings and shaft replaced recently.	
Motors	No.1		O.K.		
	No.2		O.K.		
Starters			O.K.		
			RANNA		
1. Low Lift Station					
Pumps	No.1	Ceygma	O.K.		
	No.2	Ceygma	"		
Motors	No.1	Crompton-Greaves	O.K.		
	No.2	"	"		
Starters			O.K.		

EQUIPMENT		TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
W E E R A K E T I Y A (Local Auth.)					
1. Low Lift Station					
Pumps	No.1	Godwin	O.K.		
	No.1	"	"	Pump shaft filled and machined.	
Motors	No.1		O.K.	Rewound recently.	
	No.2		"		
T I S S A M A H A R A M A (Local Auth.)					
1. Low Lift Station					
Pumps	No.1	Sigmund Pulsometer	O.K.		
	No.2	"	"		
Motors	No.1	Crompton-Parkinson	O.K.		
	No.2	"	"		
B E L I A T T E (Local Auth.)					
1. Low Lift Station					
	No.1	Ceygma	O.K.		
	No.2	"	"		
Motors	No.1	Crompton Greaves	O.K.		
	No.2	"	"		
Starters			"		

EQUIPMENT		TYPE/MAKE	PRESENT CONDITION	PAST MTCE HISTORY	OBSERVATIONS
			KAMBURUPITIYA (Local Auth.)		
I. Low Lift Station					
Pumps	No.1	Ceygma	O.K.		
	No.2	"	"		
Motors	No.1	Gould	O.K.		
	No.2	"	"		
Starters			O.K.		
			AKURESSA (Local Auth.)		
I. Low Lift Station					
Pumps	No.1	Jacuzzi	O.K.		
	No.2	"	"	Bearings replaced	
			MIDDENIYA (Local Auth.)		
I. Low Lift Station					
Pumps	No.1	Sigmund Pulsometer	O.K.		
	No.2	Ceygma - Engine Driven	"		
Motor	No.1	Crompton-Greaves	O.K.		
Starter		Memota			

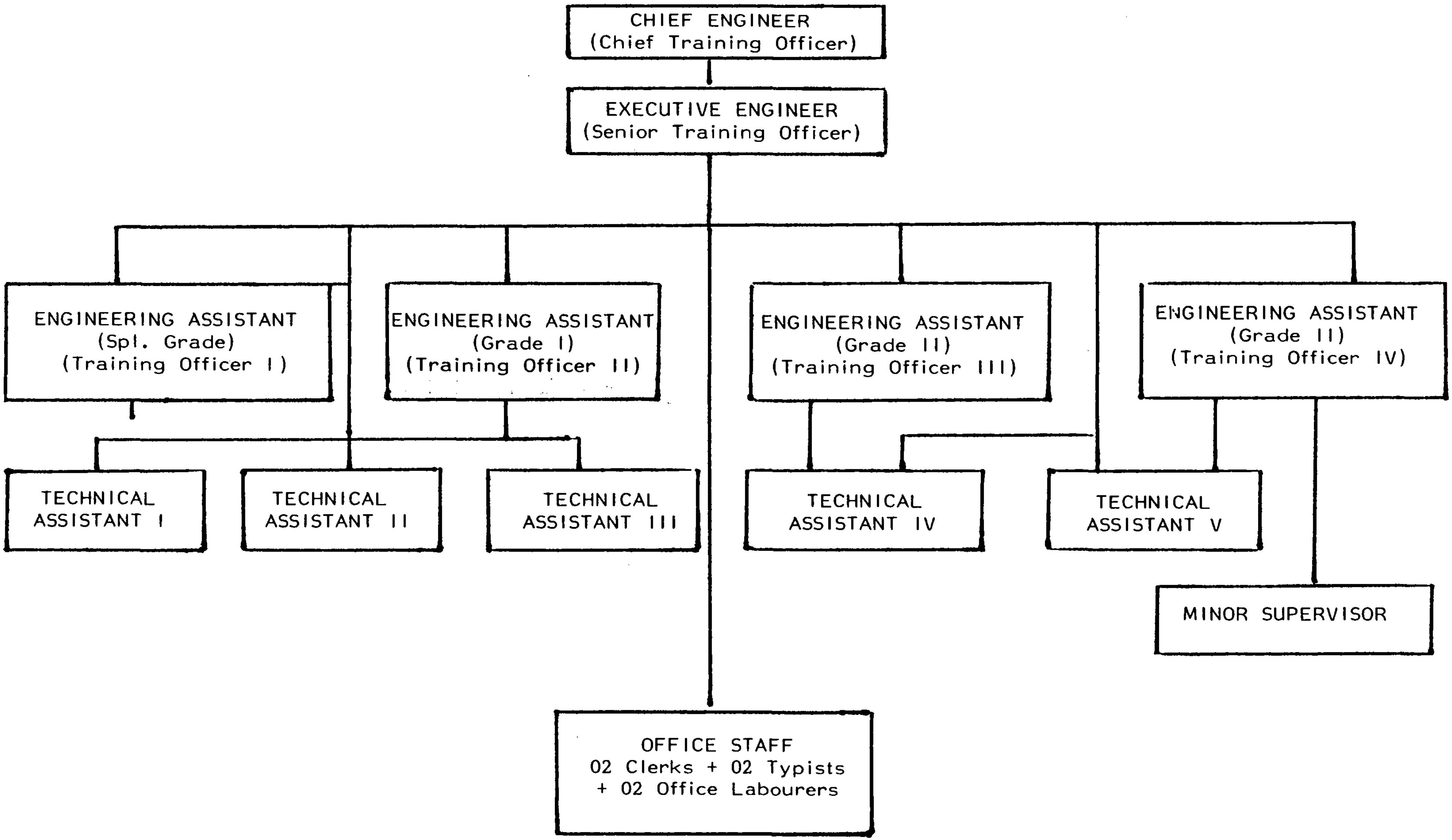
APPENDIX 5

Breakdown Maintenance Tasks, May-July 1982

Plant	Equipment	Problem	Corrective Action
MAY 1982			
1. Galle	Low lift pumps	1. Noisy operation caused by broken ratchets. 2. Broken pump suction strainers causing foreign objects to clog impellers	1. New ratchets ordered. 2. New strainers locally fabricated and fitted
2. Galle	Starter for backwash pump	Burnt out	Coil replaced
JUNE 1982			
1. Akuressa	Submersible Motor Starter	Starter trips	Cleaned starter contacts
2. Kataragama	Submersible pumps Nos. 1 and 2.	Dropping of pump capacity	Pumped and motor stripped and cleaned, refilled with distilled water.
3. Galle	Backwash Pump No.2	This pump has never been used due to to excessive vibration	Aligned pump and motor shafts
4. Walasmulla	Motor Starter	Burnt Coil	Coil sent to w/shop for repairs
5. Baddegama	Motor Starter	Tripping	Cleaned Starter Contacts
JULY 1982			
1. Galle	High lift pump motor	Reduced Current Draw	Replaced worn brushes Machined slip rings
2. Weeraketiya	Low Lift Pump	Pump Shaft Sticking	Shaft filled and machined Motor re-wound(?)
3. Akuressa	Closed Coupled Pump		Replaced shaft bearings Baked Motor (?)

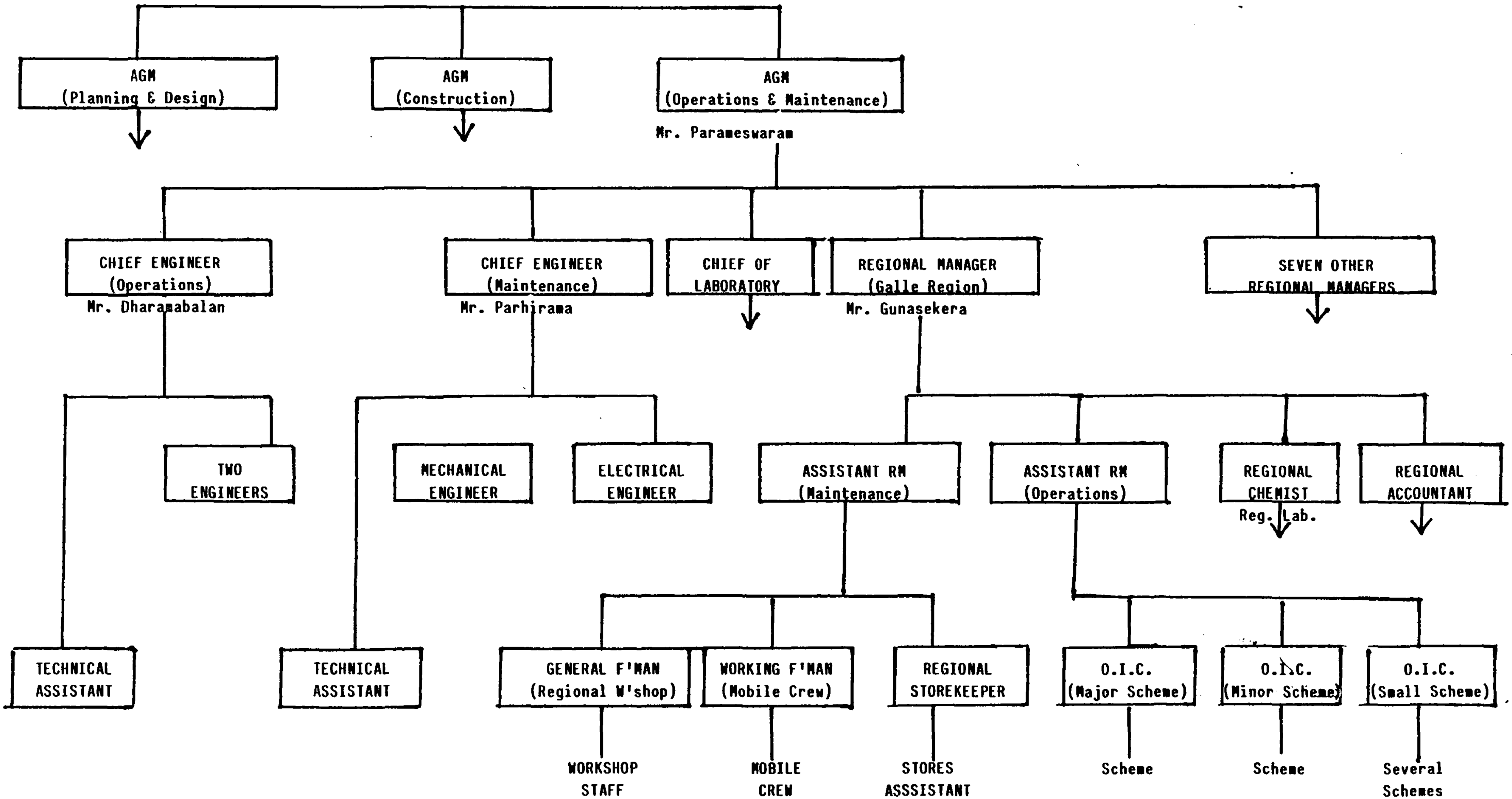
APPENDIX 6

Organisation Chart - Training Section



APPENDIX 7

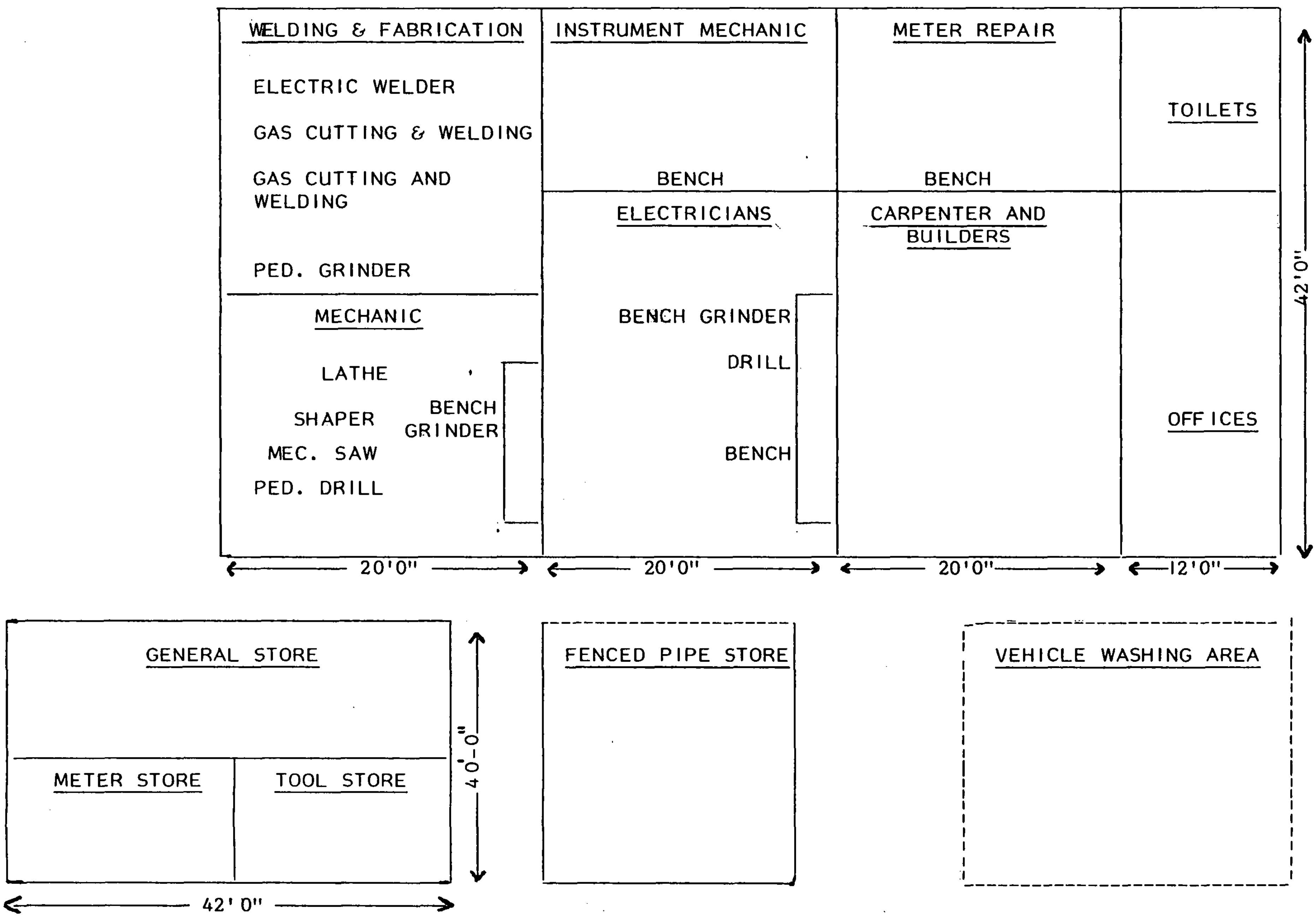
PROPOSED ORGANISATION CHART FOR OPERATIONS AND MAINTENANCE AT H.Q. AND IN GALLE REGION



APPENDIX 8

Sketch Plan of Proposed Regional Workshop and Stores

Not to Scale



APPENDIX 9

Regional Workshop - List of Tools and Equipment Needed, With Estimated Costs.

Building Cost

		RS
Cost of Building 72' x 42' @ 150 Rs/Sq.ft.	=	454,000
Construction Site Development Cost @ 20%	=	91,000
Professional Services (design supervision @ 20%)	=	91,000
Cost of Building	=	636,000

Welding Shop

Welding Equipment:- Electric, Gas Welding and Cutting	=	52,500
Minor Items:- Protective Clothing, Files, Hammers, vice, plate cutting machine	=	52,500
Total Cost	=	105,000
Plus 20% Contingencies	=	21,000
		126,000

Electrician Shop:

Instruments including AVO. Voltmeter, Ammeter and Instrument Mechanics Testing equipment	=	35,000
Small Tools:- Grinder, Drill and Spanners	=	23,000
Total Cost	=	58,000
Plus 20% Contingencies	=	11,600
	=	69,600

Mechanics Shop

Major Items of Mechanical Equipment:- Lathe, Shaping Machine, Pedestal Grinder, Drilling Machine and Lifting Gear	=	420,000
Minor Tools:- Spanners, Drills, Instrument for Measuring Machine Tools	=	70,000
Total	=	490,000
Plus 20% Contingencies	=	98,000
		588,000

CARPENTER SHOP

Circular Saw and Hand Tools		=	70,000
	Plus 20% Contingencies	=	14,000
		=	84,000

METER SHOP

Meter Repair Tools		=	35,000
	Plus 20% Contingencies	=	7,000
			42,000

Cost of Equipment	=	909,600
Cost of Building	=	636,000
Total Cost of Equipment and Building	=	1,545,600
		($77300)

APPENDIX 10

REGIONAL STORES - BUILDING COST ESTIMATES

		RS
Regional Stores 42' x 50' @ 150 Rs/sq.ft.	=	315,000
Plus 20%	=	62,000
Plus 20%	=	62,000
		439,000
Plus cost of additional fenced pipe store and washing area for vehicles	=	211,000
Total cost of building	=	650,000
		=======
		($32,500)

APPENDIX II

Instruction Manual
BOW 24

INSTALLATION, OPERATION
AND MAINTENANCE OF
SPP CENTRIFUGAL PUMPS

TYPE HSR2

INSTALLATION

OPERATION
- Fault finding chart

DISMANTLING & REASSEMBLING
- Introduction and Service Data
- Sectional Arrangement and illustrations
- Progressive dismantling
- Reassembly

MAINTENANCE
- Grease Lubrication Chart

SIGMUND PULSOMETER PUMPS LTD.,
OXFORD ROAD, READING, BERKS, ENGLAND
A member of the SPP Group

Instruction Manual

INSTALLATION, OPERATION AND MAINTENANCE OF SPP CENTRIFUGAL PUMPS

General Instructions

INSTALLATION

LOCATION OF UNIT

The pump should be placed as near the liquid source as practical so that a short direct suction pipe may be used. The pump should be accessible for inspection and repair work and headroom be provided for crane, hoist or tackle if the pump is heavy.

PIPING

Both the suction and discharge lines should be independently supported near the pump so that no strain will be thrown on the casing.

Suction Piping

The suction line should be as short and straight as possible and containing a minimum number of bends. Any bends necessary should have large radii. Generally the suction pipe is made one or two sizes larger than the pump suction branch. For pumps operating with suction lift no valves other than a foot-valve should be placed in the suction line. All these precautions ensure the maximum available suction head on the pump. Reducers must be eccentric if installed in a horizontal position (Fig. I). A straight taper reducer (Fig. II) should not be used in a horizontal suction line, because it may form an air pocket (IIA) in the top of the reducer and the pipe.

It is very important to have the suction line air-tight and to avoid undulations in which air may collect and destroy the vacuum. Where adverse suction conditions may cause the pump to lose its prime, the use of an external automatic priming device such as a vacuum pump is recommended.

Ensure that the system is free from foreign matter such as pipe scale, welding beads, dirt, etc. It is suggested to flush the whole system before going into operation. If possible use a temporary suction screen for removal of material in the pipe system.

For a given suction lift, suction capacity depends on the temperature of the liquid. For water 70°C (160°F) or above, care should be taken to ensure that enough pressure is available at the impeller entry to prevent vaporisation.

Foot Valve

Should have a free area of at least one and a half times the area of the suction pipe.

An efficient strainer should be provided to prevent foreign matter from being drawn into the pump or choking the foot valve. When there is any refuse such as sticks, twigs, leaves, etc., in the water, a larger outside screen, or a large basket strainer should be placed around the suction inlet to prevent choking the strainer. This screen should have sufficient openings to keep the flow through it below 0.6m (2 feet) per second.

Discharge Piping

Generally the discharge piping is made one size larger than the pump discharge branch size. The discharge line should be short and direct with the least number of bends and fittings, thus minimising the head lost by friction. A non-return valve and discharge valve are usually placed in the discharge line. The non-return valve is to protect the pump from excessive back pressure and reverse rotation of the unit, and to prevent back flow into the pump in case of stoppage or failure of the driver. The discharge valve is used to regulate the flow. The non-return valve is placed between the discharge valve and the pump so that it may be inspected or repaired without emptying the discharge line.

Foundation

The foundation should be substantial to reduce vibrations and rigid enough to avoid any twisting or misalignment.

Alignment

The pump driver, if supplied, is correctly aligned on its baseplate at the factory. A certain amount of deformation of the baseplate is possible during transit and it is therefore essential to check alignment before going into operation. The pump shaft should be checked for angular and parallel alignment. A flexible coupling will not compensate for misalignment. Inaccurate alignment results in vibration and excessive wear on the bearings, sleeve or shaft and wear-rings.

The check for angular alignment (Fig. III) should be made by inserting a pair of inside calipers or taper gauge (IIIA) at four points, spaced at 90° intervals, between the coupling faces which must be within 0.07 mm (0.003"). A check for parallel alignment (Fig. III) is made by placing a straight edge (IIIB) across the coupling rims at the top, bottom and at both sides. The unit will be in parallel alignment when the straight edge rests evenly on the coupling rim at all positions.

Grouting

A space of approximately 25mm (1") should be left between the baseplate and top of the foundation to be filled with grouting. After the grouting has dried the foundation bolts should be firmly tightened and alignment re-checked.

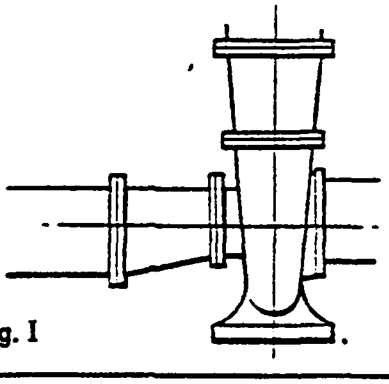


Fig. I

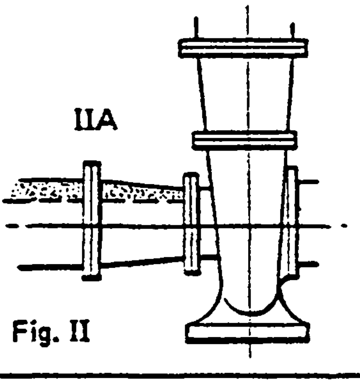


Fig. II

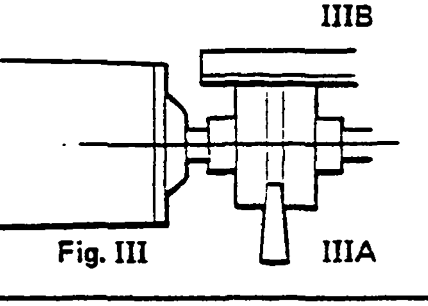


Fig. III

OPERATION

ELECTRIC MOTOR DRIVE

Instal a starter with overload protection to prevent the motor being damaged by overload. The overloads should be set so that they trip if the current exceeds the nominal current of the motor (see motor nameplate) by 10%.

(N.B. Fire pumps may require exemption from this note)

BEFORE STARTING

The pump is ready for starting when:

a) Pump base-plate is grouted and bolted to the foundation.
b) Pump and driver are correctly aligned.
c) Bearing lubrication is provided.
d) Stuffing-box has been packed or fitted with seal.
e) Cooling water is supplied to bearing – if specified.
f) Prime-mover has been checked for correct direction of rotation.
g) All rotating parts are found free by turning by hand.
h) Pump is primed. Never run a pump dry. The liquid in the pump serves as a lubricant for close running fits within the pump and the pump may be damaged if operated dry for an extended period. The pump may be primed by using an ejector, exhauster or vacuum pump. If a foot valve is used in the suction line, the pump may be primed by venting and filling the casing with liquid.

STARTING

Start the pump with discharge valve closed and bring it up to speed rapidly. When pressure is reached, open discharge valve slowly. Do not operate unit for prolonged periods with closed discharge valve, so as to avoid overheating.

The pump should be shut down at once and the trouble corrected if the pump is running at its rated speed and found to have any of the following defects:

a) No liquid delivered.
b) Not enough liquid delivered.
c) Not enough pressure.
d) Loss of liquid after starting.
e) Vibration.
f) Motor runs hot.
g) Pump bearing over-heating.

RUNNING

While the pump is running, a periodic inspection should be made of:

a) Stuffing-box

Keep stuffing-boxes (if soft packed, not fitted with mechanical seal) so that there is sufficient leakage to lubricate the packing.

b) Bearing

Check the bearing for temperature which should not exceed 70°C (160°F).

c) Alignment

Successful operation of the pumps depends on accurate alignment. It is recommended to re-check the alignment after preliminary run.

OPERATING TROUBLES AND THEIR CAUSE

	Cause	Defects							
		No liquid delivered	Not enough liquid delivered	Not enough pressure	Loss of liquid after starting	Vibration	Motor runs hot	Cavitation (Noise)	Pump bearings over-heat
1	Pump not primed	•							
2	Speed too low	•	•	•					
3	Speed too high						•	•	
4	Air leak on suction	•	•		•	•		•	
5	Air leak in mechanical seal		•		•				
6	Air or gas in liquid			•	•	•		•	
7	Discharge head too high (above rating)	•	•	•			•		
8	Suction lift too high				•				
9	Not enough suction head for hot liquid		•						
10	Inlet pipe not submerged enough	•	•		•	•		•	
11	Viscosity of liquid greater than rating		•	•			•		
12	Liquid heavier than rating						•		
13	Insufficient nett inlet head	•	•		•	•		•	
14	Impeller plugged up	•	•			•			
15	Wrong direction of rotation	•	•	•					
16	Excessive wear ring clearance		•	•					
17	Damaged impeller		•	•		•			
18	Rotor binding						•		
19	Defects in motor						•		
20	Voltage and/or frequency lower than rating						•		
21	Lubricating oil dirty, contaminated								•
22	Foundation not rigid					•			
23	Misalignment of pump and driver					•	•		•
24	Bearing worn					•			
25	Rotor out of balance					•			•
26	Shaft bent					•	•		•
27	Impeller too small			•					

General Instructions

MAINTENANCE

ROUTINE TEST

1) Hand test bearing housing for any sign of temperature rise. Temperature should not exceed 70°C (160°F).	A rise in temperature may indicate the early stages of bearing trouble.
2) Listen for any unusual noise developing.	Look for a Loose stud bolts holding coupling guard. b Worn coupling. c Air trapped in pump. d Hydraulic noise, if the suction conditions have changed, causing minor cavitation. e Small solids entering pump.
3) Note the suction gauge reading and confirm that it is usual.	If it is higher than normal, find out why: a Has a valve in the supply system been partially closed? b Has the static suction lift increased?
4) Note the discharge gauge reading and confirm that it is as usual.	If lower than normal: a Inspect for serious leakage anywhere, owing to pipe fracture. b A valve in the delivery line may have been fully opened, which was previously partially closed.

Grease Lubrication of ball and roller bearings: sleeve bearings (pump internal and lineshaft): lantern bushes and soft packing stuffing boxes.
Refer to sheet following overleaf regarding recommended greases and service.

Initial Greasing

During pump assembly, grease should be thoroughly worked into all parts of a bearing. The space in the housing is to be lightly packed with grease during assembly. It is sufficient to have the housing up to one third full. Over filling can be just as harmful to a bearing as under-filling. If not corrected, the over-heating that results can cause break-down of the grease and lead eventually to the failure of the bearing.

Regreasing

Because of shrinkage or loss of grease, re-application should be carried out at intervals of three months. Immediately after re-lubrication, the temperature of the bearing will usually rise; this should soon drop to normal under continued running. If it does not, then it is likely the bearing and housing have been over filled and this should be corrected.

Take out the lubrication fitting to allow expulsion of any excess grease: if thereupon the bearing cools, replace the fitting when grease discharge ceases.

Oil Lubrication of ball and roller bearings.

Correct oil level in the bearing housing is important. The oil should reach approximately the centre of the bottom ball or roller in the bearing.

To avoid overfilling which would cause heating owing to churning of the oil, while at the same time ensuring adequate oil level and reserve, the bearing housings are fitted with constant level oilers.

Remove the transparent container from the constant level oiler elbow and pour sufficient lubricating oil through the bearing oil filler until overflow from the elbow takes place. Invert the transparent oil container, fill with oil and replace on the elbow.

Check oil levels and top up constant level oiler container weekly.

Completely change oil after 600 hours for new bearings, then approximately every 6 months or 5000 hours.

Recommended Oils	Temperate	Tropical
Caltex, Regent, Texaco	Regal Oil PC (R & O)	Regal Oil PC (R & O)
BP	Energol CS 65	Energol CS 625
Shell	Vitrea 27	Vitrea 33
Castrol	Castrol Perfecto NN or Castrol Perfecto Medium	Castrol Perfecto NN Castrol Perfecto Medium
Gulf	Harmony 44	Harmony 53
Esso	Teresso 52	Teresso 65
Mobil	DTE Oil Heavy	DTE Oil Heavy

N.B. All oil lubricated bearings are drained before despatch from the factory and should be re-filled prior to starting up.

Grease Lubrication Chart

Maker and Grade	BALL BEARING Grease cup, grease nipple		SLEEVE BEARING Mech. lubricator, hand operated screw		STUFFING BOX Grease cup, hand operated screw	
	Standard	Water repellent	Standard	Water repellent	Lubricating	Sealing
Caltex Regent Texaco	Regal Starfak 2	Multifak EP2	Regal Starfak 2	Multifak EP2	Regal Starfak 3	Regal Starfak 3
BP	Energol LS2	Energol LS2	Energol LS2	Energol LS2	Energol LS3	Energol LS3
Shell	Alvania Grease 2	Alvania Grease 2	Alvania Grease 1	Alvania Grease 2	Alvania Grease 3	Alvania Grease 3
Castrol	Spheerol AP 3	Spheerol AP 3	Spheerol AP 2	Spheerol AP 3	Spheerol AP 3	Impervia WP
Gulf	Gulf Crown No. 3	Gulf Crown No. 3	Gulf Crown No. 3	Gulf Crown No. 3	Gulf Crown No. 3	Gulf Crown No. 3
Esso	Beacon 2	Gazark 2	Beacon 2	Gazark 2	Gazark 2	Gazark 2
Mobil	Mobilux 2 or Mobilplex 47	Mobilux 2 or Mobilplex 47	Mobilux 2 or Mobilplex 47	Mobilux 2 or Mobilplex 47	Mobilux 3 or Mobilplex 48	Mobilux 3 or Mobilplex 48
A general guide to service under normal conditions.	Regrease 2–3 months (2000hrs.) Allow any surplus to escape.		As required. Check weekly, add to container. Grease flush 3mths. interval (2000hrs.)		As required. Check weekly.	
	Housing 2/3 full max.		Change 4000 hrs. or 6 months.			

STUFFING-BOX

Installing the packing:

A) Preparation:

a) Remove all rings of old packing, and lantern ring (if fitted, Fig. 1–2): Use extractor (2A) to extract packing entirely, without damaging shaft or stuffing-box bore.

b) Clean shaft and bore of box with clean oily cloth: also the lantern ring (if fitted).

B) Fitting:

Packing can now be installed in the stuffing-box. Follow this instruction to ensure trouble-free operation of stuffing-box:

a) Insert the first ring and tap it to the bottom of the stuffing-box. Each following ring should be installed in the same manner and positioned in the stuffing-box (Fig. 1), so that "split" (1A) is advanced 90°.
Install any lantern ring in its proper position to align with the sealing connection, allowing for movement of the ring deeper into the box as the packing is compressed.

b) When the correct number of rings have been inserted the last packing ring should never protrude past the stuffing-box face, so that gland may be properly started in the stuffing-box bore (1B)

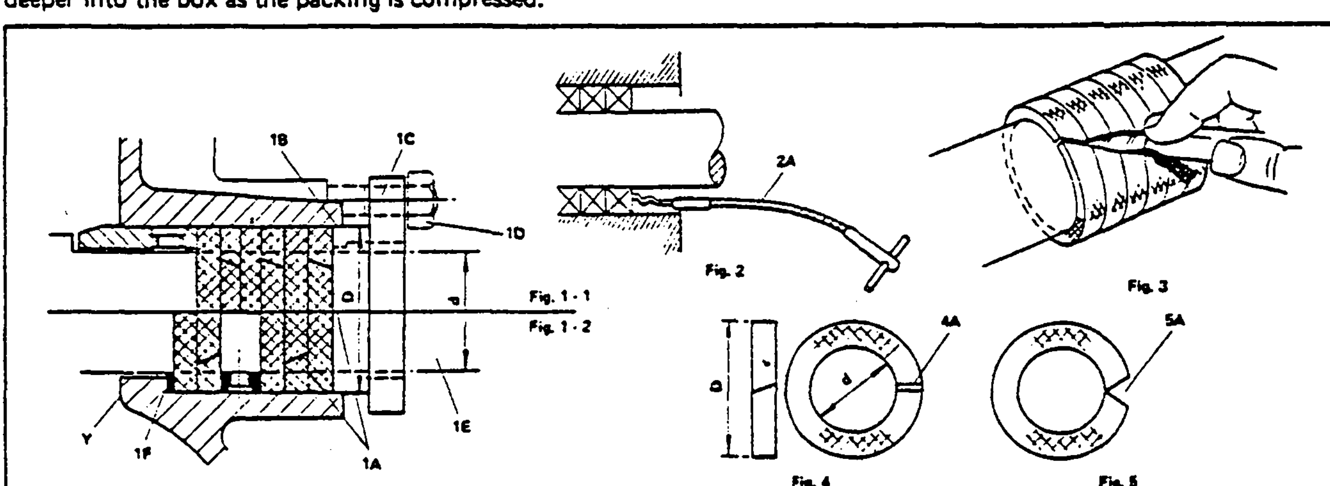
c) Install gland (1C) and tighten finger tight only. When pump has been running for ten minutes at full pressure adjust nuts (1D) by sixth turn; continue to adjust at ten minute intervals. Small leakage must be allowed to ensure the packing is lubricated.

Caution: Excessive gland pressure will cause damage by cutting off lubrication to the packing, and packing will burn and damage shaft.

If the packing is to be cut from a coil, or long length, obtain size, length and number of rings from Table 1 (if given).

Wrap the packing around a dummy shaft, equal to shaft diameter (Fig. 1–d) in the manner shown in Fig. 3. Over lapped split (4A) of the ring provide better sealing.

If packing is cut out of flat strip, the ends of packing (5A) will never seal and will develop leakage.



SIGMUND PULSOMETER PUMPS LTD · OXFORD ROAD · READING · RG3 1JD · ENGLAND
Telephone: 0734 25555 Telex: 84189 Cables: Sigmeter Reading. OOWO1 ISSUE 1 12/70

Centrifugal Pumps
types
HSR2
and HSR3

Dismantling and Reassembling

INTRODUCTION

In general, when pumps are dismantled, inspected, and/or replacement parts fitted, the work is undertaken for one of the following reasons:-

Group A

1) Because the time for regular periodic inspection has become due. Planned inspection and maintenance at predetermined intervals is a sound insurance against a forced shut-down because of failure at a most inconvenient time.

Group B

2) Perceptible fall-off in pump performance affecting capacity and pressure.
3) Excessive leakage from packed stuffing-box where first-aid adjustment is insufficient to effect a cure.
4) Excessive and continuous vibration or persistent noisy operation.

Dismantling procedure is dependent upon 1, 2, 3 or 4 above.

In those cases of Group A inspections, these are done at a pre-selected time and the programme is usually *complete dismantling,* so that all parts can be cleaned, examined and measured for wear, etc.

Group B will vary with pump type, and to reveal the source of the trouble, only partial dismantling (see a, b, c) may be needed.

If possible, the pumps should be moved into the shop when a complete overhaul is needed. A higher standard of cleanliness can be obtained in the shop and better lifting facilities, tools, etc. are available.

Table 1 – Soft Packed Stuffing Box data

Pump size	Packing size				Size of ring i.d. x o.d.		No. of rings /box
	Square section		Approx. length one ring				
	inch	mm	inches	mm	in. x in.	mm x mm	
HSR2A4	7/16	11	7 7/8	200	1 5/8 x 2 1/2	41.5 x 63.5	5
HSR2B 1½ 2 HSR2A 2 3	3/8	9.5	6 11/16	170	1 3/8 x 2 1/8	35 x 54	5
HSR3B 3	7/16	11	7 7/8	200	1 5/8 x 2 1/2	41.5 x 63.5	5

Table 2: *initial running clearances (Fig. 6) NOTE: Clearances diametral. not radial*

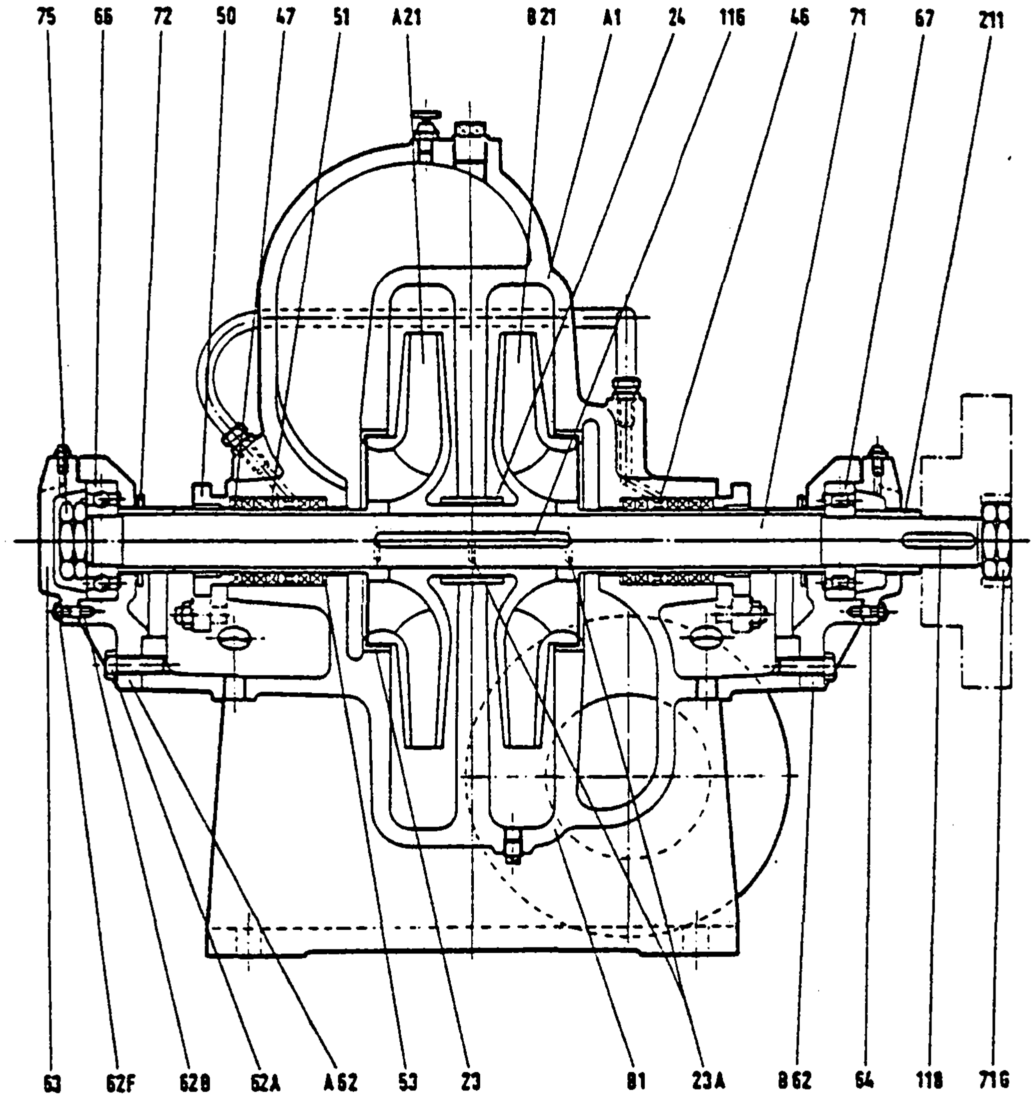
Pump size	Impeller/case wear ring		Impeller/Interstage neckbush	
	D1 – d1		D3 – d3	
	inch	mm	inch	mm
All 1½,2 HSR2A 2 3	0.014	0.35	0.007	0.18
HSR2A 4	0.016	0.41	0.006	0.15
HSR3B 3	0.015	0.38	0.008	0.20

Table 3 – Sizes of bearings

Pump size	Item 66: ball thrust bearing	Item 67: roller journal bearing
HSR2A 4	B.S. BRM 1¼	B.S. RRM 1¼
HSR2B 1½,2 HSR2A 2 3	B.S. BRM 1	B.S. RRM 1
HSR3B 3	B.S. BRM 1¼	B.S RRM 1¼

TYPICAL SECTIONAL ARRANGEMENT

with principal parts numbers and description.
HSR2 two stage split case pump with soft packing stuffing boxes.



Item No.	Description	Item No.	Description
A1	Casing, top half	B62	Bearing housing, drive end
B1	Casing, bottom half	63	Bearing cap, thrust end
A21	Impeller, thrust end	64	Bearing cap, drive end
B21	Impeller, drive end	66	Ball thrust bearing
23	Case wear ring	67	Roller bearing
23A	Case wear ring (and interstage neckbush) dowels	71	Shaft
24	Interstage neckbush	71G	Coupling locknut
47	Sleeve	72	Liquid thrower
50	Gland	75	Bearing retaining nut
51	Gland packing	116	Impeller key
A62	Bearing housing, thrust end	118	Coupling key
		211	Coupling sleeve

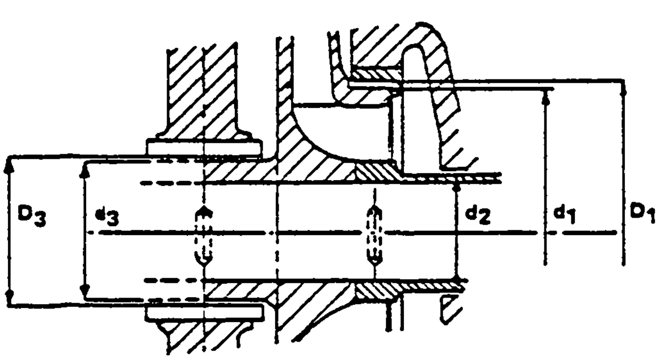


FIG. 6

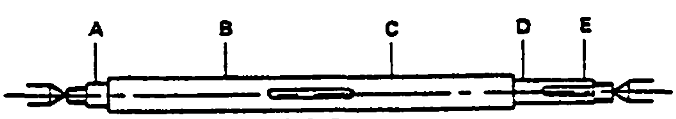


FIG. 7

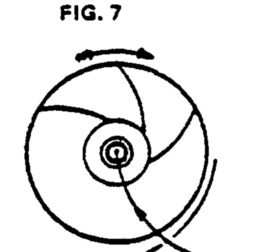


FIG. 8.

DISMANTLING

(a) To examine shaft sleeve surfaces.

1. Take off nuts and draw glands (50) off gland studs.
2. Take nuts off all casing joint studs.
3. Loosen both dowels by screwing nuts down, then screw back nuts and prise out dowels.
4. Equally screw in forcing set screws to start plain half casing (A1) off branch half (B1).
5. Lift plain half casing off studs and clear of impellers, and place to one side.
6. If gland packing (51) can — with lantern rings (46) — now be taken out or be drawn along sleeves (47) towards liquid throwers (72), the condition of the sleeves through the packing can be examined: but if need for further dismantling is likely, sleeve examination and check may more conveniently follow rotating element removal as below.

(b) To remove rotating element, check case wear ring clearances, and examine wear ring and impeller mating surfaces.

7. Take out bolts (62A) securing bearing housings (A62, B62) to branch half casing.
8. Lift entire rest of assembly out and clear.
9. If not already done (see 6 above), the glands, packing and lantern rings can now be drawn aside to expose packing contact surfaces of sleeves for examination.
10. Ease case wear rings outwards on the impellers. It may then be possible (from the impeller sides) to try feelers in clearances between wear rings and impellers; or obvious wear may be revealed, and the condition otherwise of wear ring bores and impeller eye outsides be seen, by completely sliding the rings off the impeller eyes, and rotating rings and impellers for inspection. However if need to dismantle for renewals appears likely, clearances may be more conclusively checked by individually gauging parts afterwards.

Enlargement of clearances between impellers and wear rings and interstage neckbush (24) produces increase in internal leakage with resultant loss of head and efficiency. Although it is recommended that new wear rings and interstage neckbush be fitted to restore original clearances when these have doubled, other considerations have to be taken into account, e.g. is the head loss not acceptable?: or would reduced running costs justify more frequent renewal?
See table 2, for original clearances (note these are diametral, viz. D1—d1 etc. Fig. 6).

(c) To dismantle as far as removal of impellers.

11. Take off nuts (62F) and take away thrust bearing cap (63).
12. Take off both thrust bearing retaining nuts (75).
13. Tap or draw off thrust bearing housing (A62) with ball thrust bearing (66).
14. Pull off liquid thrower.
15. Slip off gland, packing, lantern ring, packing stop (stuffing box insert, 53) and nearside case wear ring (23).
16. Pull off sleeve (47) and impeller (A21) — by tapping far side impeller with rawhide mallet if necessary — then take away neck bush, pull off impeller (B21) and take away far side case wear ring.

(d) To dismantle the remainder of rotating element.

17. Take off both coupling locknuts (71G).
18. Draw (or tap) off driven half coupling and take coupling key (118) out of shaft.
19. Pull off coupling sleeve (211).
20. Tap or draw off drive end bearing housing (B62) with roller bearing (67).
21. Pull off liquid thrower.
22. Slip off gland, packing, lantern ring and packing stop.
23. Pull off sleeve and take impeller key (116) out of shaft.

After dismantling

(a) Wash all old lubricant from ball and roller bearings and housings with kerosene or white spirit, and dry bearings thoroughly by spinning by hand, or *gently* with clean dry compressed air. Renew them if they do not then rotate smoothly with no sign of jamming, and freely but without slackness; or if running surfaces of balls, rollers or races show any deterioration. Coat bearings with rust preventive oil and wrap in greaseproof paper.

(b) Mount shaft between point centres (Fig. 7) or on rollers, and place stem of dial indicator in contact with shaft. Set the indicator dial at zero and turn the shaft slowly by hand. Reading at any point A, B, C, D and E must not vary more than 0.05 mm (0.002").

(c) Examine the shaft sleeves for wear and check for truth. It is important that the surfaces of the sleeves which run in the stuffing box against soft packing, are concentric and not scored. If the truth of the shaft itself is satisfactory, remount the shaft as in (b) but with the sleeves refitted in their proper positions, and check the sleeves for truth, with dial indicator, at various packing contact positions. Indicator readings must not vary more than 0.08 mm (0.003").
If scoring is not heavy, the sleeves can be reground to provide new surfaces, but there is a definite limit to the amount of reduction in diameter that can be tolerated. Sleeve diameter — (d2, Fig. 6) — in the stuffing box can be reduced up to maximum 1.0 mm (0.04") below the initial diameter, to provide better surfaces.
Surface finish of the sleeves should be 20.30. CLA.

(d) Scour any rust or scale from internal iron non-fitting surfaces and immediately repair or renew any previous coating.
Clean all threads with kerosene followed by wire brushing, and wrap shaft threads with protective canvas adhesive tape.

(e) If a unit is not to be reassembled immediately, brush all bright iron and steel surfaces with Shell Ensis rust preventive fluid.
Protect all parts against loss, weather or mechanical damage.

Before reassembly

(f) Re-examine all old parts intended for re-fitting. Worn, damaged or corroded parts should either be re-conditioned or, if beyond this, be discarded and replaced by new.

(g) Ensure that all parts to be refitted (especially new parts) are free from burrs, with screw threads and abutting faces clean and free from damage.

(h) Replace gaskets in similar material and *same thickness.*

REASSEMBLY

(a) **To assemble rotor**

1. Lightly smear shaft (71) with clean good quality grease.
2. Fit impeller key (116) in shaft.
3. Push impellers (A21, B21) onto shaft so that they locate centrally over key, with interstage neck bush (24) between them on their abutting hubs, their inlets facing outwards to shaft ends, and vanes directed as Fig. 8 with respect to coupling end of shaft and positions of casing inlet and outlet branches.
4. Coat flange ends of sleeves (47) with jointing paste.
5. Push sleeves, keywayed flange ends foremost, onto shaft to locate on key projections and abut impellers.
6. Position case wear rings (23) on impellers, and thread packing stops (stuffing box inserts, 53)— chamfered sides foremost — lantern rings (46) and glands (50)— flanges outermost — onto sleeves.
7. Tap roller bearing (67) outer race into drive end bearing housing (B62), smear bores of this and non-drive end housing (A62) with grease, insert 'go' sides of liquid throwers (72) and place throwers (foremost) and housings onto shafts for throwers to abut sleeves.
8. Lightly pack both sides of ball bearing (66) with grease lubricant, tap onto shaft non-drive end and into housing, and add first bearing retaining nut (75).
9. Lightly pack both sides of roller bearing with grease lubricant and tap onto shaft to locate in outer race in housing.
10. Push on coupling sleeve (211).
11. Lightly pack roller bearing cap (64), and smear bore, with grease lubricant: then register cap (spigot and flange foremost) over coupling sleeve, onto fixing studs and into housing, and secure with nuts as 15 below.
12. Fit coupling key (118) in shaft, register pump half coupling on shaft and key and tap on to abut coupling sleeve, and screw on first coupling locknut (71G).
13. Tighten first retaining nut and locknut and adjust to give equal shaft projections at both ends. Shaft drive end should then be flush with coupling face.
14. Add second nuts at both shaft ends and, with assembly firmly tightened by first nuts, tightly lock second nuts against first.
15. Lightly fill ball bearing cap (63) with grease lubricant, register on studs (62B) and in bearing housing, and secure with nuts (62F).

(b) **To check rotor assembly**

16. Support bearing housings on V – blocks: draw glands, lantern rings, packing stops and wear rings from their positions and rest close as possible to bearings, and check truth of impeller eye outsides and of sleeves through packing, by rotating in contact with dial indicator.
17. If reading at any point varies more than 0.08 mm (0.003"), slack off locknuts and recheck. If error disappears, dismantle rotor and check that shaft shoulders, and end faces of all other parts, are free of foreign matter and square to axis to within 0.025 mm (0.001"): if error unchanged, dismantle and check if shaft is out of truth. Rectify any deviations, reassemble and check again.

(c) **To assemble rotor in casing**

18. Oil the sleeves and impeller eye outsides, and position the case wear rings on the impellers with their (and the interstage bush) dowel (23A) flutes vertical.
19. Place rotor, right end round, into branch half casing (B1), sliding bearing housings round into place and making sure they rest right home by checking that the thinnest feeler cannot be inserted below the shaft, between the housing spigots and their seatings. Secure housings to casing with bolts (62A).
20. Insert case wear ring and interstage bush dowels and push home clear of branch half casing joint flange.
21. Make sure shaft turns freely by hand.
22. Place gasket on bottom half casing joint face, fitting neatly adjacent to stuffing boxes.
23. First making sure forcing set screws are screwed back clear of joint face, turn plain half casing (A1) with flange towards branch half and right end round, register on branch half casing studs, and insert dowels.
24. Apply nuts to studs, put in bolts or socket head screws, and tighten.
25. Repeat 21.
26. Lubricate bearings and pack glands as described previously.

Pump is now ready for recoupling to driver, and recommissioning.

APPENDIX 12a

Example : Preventive Maintenance Inventory Data Sheet

STWA
PLANT RECORD

MECHANICAL DATA	ELECTRICAL DATA	MAINTENANCE PERIOD	MAINTENANCE SCHEDULE
Make	Make	Weeks	Number
Supplier	Supplier		Class A. B. C.
Type	Type	ADDITIONAL DATA	
Serial No.	Serial No.		
Drawing No. File No.	Drawing No. File No.		
Date of Purchase	Date of Purchase		
Estimated Life	Estimated Life		
Capacity	Rating		
Horse Power	H.P. K.W. Speed		
Head	Volts Phase Hz		
Speed	Amps Overload		
Weight (Max)	Winding Connected		
Coolant	Weight (Max)		
Lubrication	Frame Size		
Other Details	Bearings D.E.		
	N.D.E.		
	Other Details		

Year | DUE:- A. B. C. | COMPLETED:- R or S | R = Rectified | S = Serviceable

Year																												
19	Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	Week No.	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
19	Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	Week No.	14	15	16	17	18	19	20	21	22	23	24	25	26
		27	25	29	30	31	32	33	34	35	36	37	38	39		40	41	42	43	44	45	47	48	48	49	50	51	52

Kalamazoo
BUSINESS SYSTEMS
1030731-611
TITLE BELOW
THIS LINE

YEAR	MANUF'D	DESCRIPTION	PLANT No.

Appendix 12a continued

Year	DUE:- A. B. C. COMPLETED:- R or S R = Rectified S = Serviceable																											
	Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	Week No.	14	15	16	17	18	19	20	21	22	23	24	25	26
19		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
	Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	Week No.	14	15	16	17	18	19	20	21	22	23	24	25	26
19		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
	Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	Week No.	14	15	16	17	18	19	20	21	22	23	24	25	26
19		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
	Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	Week No.	14	15	16	17	18	19	20	21	22	23	24	25	26
19		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
	Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	Week No.	14	15	16	17	18	19	20	21	22	23	24	25	26
19		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
	Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	Week No.	14	15	16	17	18	19	20	21	22	23	24	25	26
19		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
	Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	Week No.	14	15	16	17	18	19	20	21	22	23	24	25	26
19		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
	Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	Week No.	14	15	16	17	18	19	20	21	22	23	24	25	26
19		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

APPENDIX 12b

Example : Preventive Maintenance History Sheet

MAINTENANCE - REPAIRS - OVERHAULS			
DATE	DESCRIPTION OF REPAIR	BY WHOM	MATERIAL COSTS

Kalamazoo 537659 611 N TITLE BELOW THIS LINE

YEAR OF MANUFACTURE	DESCRIPTION	PLANT NO

Appendix 12b continued

MAINTENANCE - REPAIRS - OVERHAULS			
DATE	DESCRIPTION OF REPAIR	BY WHOM	MATERIAL COSTS

APPENDIX 12c

Maintenance Instruction Schedule (part only)

S.T.W.A. Tame Division — **MAINTENANCE ENGINEERING SECTION**

MAINTENANCE SCHEDULE No. E104

Works : Booster Stations (Instrumentation) — CLASS C

Description

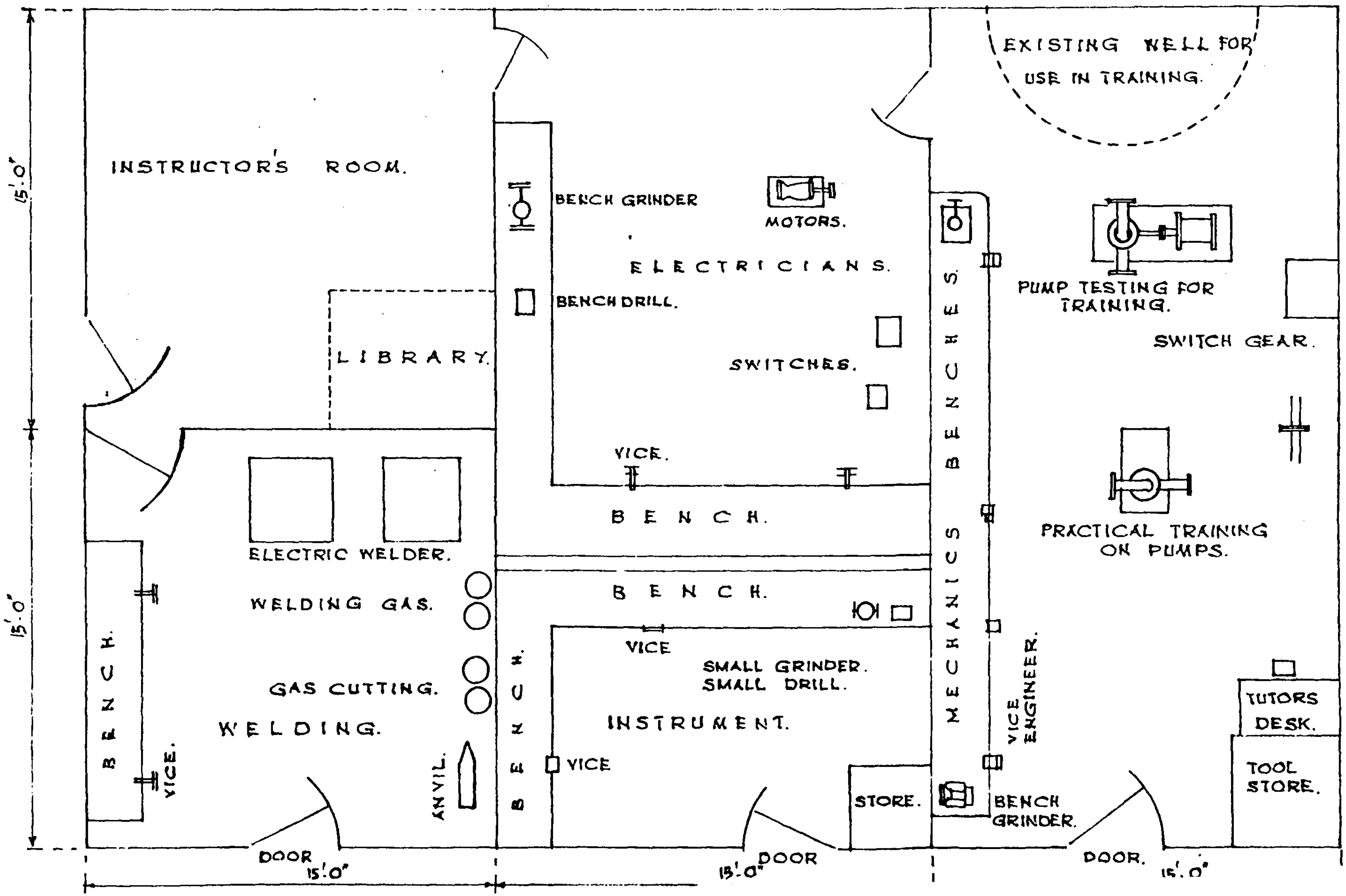
1. Visual Check Note Gauges Setting & Pump Selection. Build up pressure in system.
2. Remove safety shutdown 5"/16 Copper Pipe Work from Mains Supply check that Station shutdown.
3. Rod out suction pressure $\frac{3}{8}$" cocks.
4. When station shuts down isolate supply.
5. Remove top and bottom covers of control panel.
6. Clean contacts on pressure gauges and replace covers (3No.)
7. Clean contacts on control relays (3No.)
8. Switch on panel.
9. Connect suction pipe and restore pressure.
10. Wait for safety shut down time delay to operate.
11. Disconnect delivery pipes and rod out $\frac{3}{8}$" cock.

P.T.O.

12.	Reconnect delivery pipes and switch on water supply.
13.	Test duty and standby pump by re-adjusting gauge settings.
14.	1 with 2 ; 2 with 1 etc.
15.	Replace covers.
16.	Reset station setting.
17.	Report

APPENDIX 13

SKETCH PLAN OF PROPOSED MAINTENANCE TRAINING CENTRE



APPENDIX 14

MAINTENANCE TRAINING CENTRE - LIST OF TOOLS AND EQUIPMENT NEEDED WITH ESTIMATED COSTS

1. ELECTRICAL SECTION

		RS
Tutors desk and chair	)	7,000
Work Benches fitted with lockable drawers	)	
Mechanics vices	)	
Bench Grinder	)	24,500
Bench Drilling Machine	)	
Electrical measuring instruments		38,500
Electrical Tools		35,000
Motors - squirrel cage, wound rotor		60,000
Starters and switchgear		40,000
Wiring, plugs, sockets, switches, fuse boards		10,000
		215,000
		=======

2. MECHANICAL SECTION

Tutors desk and chair	)	
Work benches fitted with lockable drawers	)	
Lockable steel store cupboards	)	24,500
Engineering vices	)	
Bench grinder	)	
Bench drill	)	15,750
	)	
1 Set pipe screwing equipment		
1 Set large spanners	)	
Measuring instruments	)	35,000
2 Sets files	)	
Flowmeter		35,000
Miscellaneous Equipment		29,750
Pumps and motors, screwed and bolted pipes, flow meter tubes, chlorinators, mild steel test pieces, paperwork.	)	240,000
		380,000
		=======

3. INSTRUMENT SECTION

		RS
Tutors desk and chair	)	
Bench	)	22,750
Small grinder	)	
Small bench drill		
Instrument vices		
Small spanners	)	
Instrument mechanics tools	)	33,250
Flow metering equipment		120,000
Test instruments		35,000
		211,000

4. WELDING SECTION

Tutors desk and chair	)	
Bench	)	12,250
Engineering vices	)	
Electric welding sets		
Gas welding set	)	
Gas cutting set	)	19,250
Anvil	)	
Mild steel plate and bar		2,000
Grinding machine - pedestal type		12,250
Miscellaneous equipment		22,750
Protective clothing		3,500
		72,000