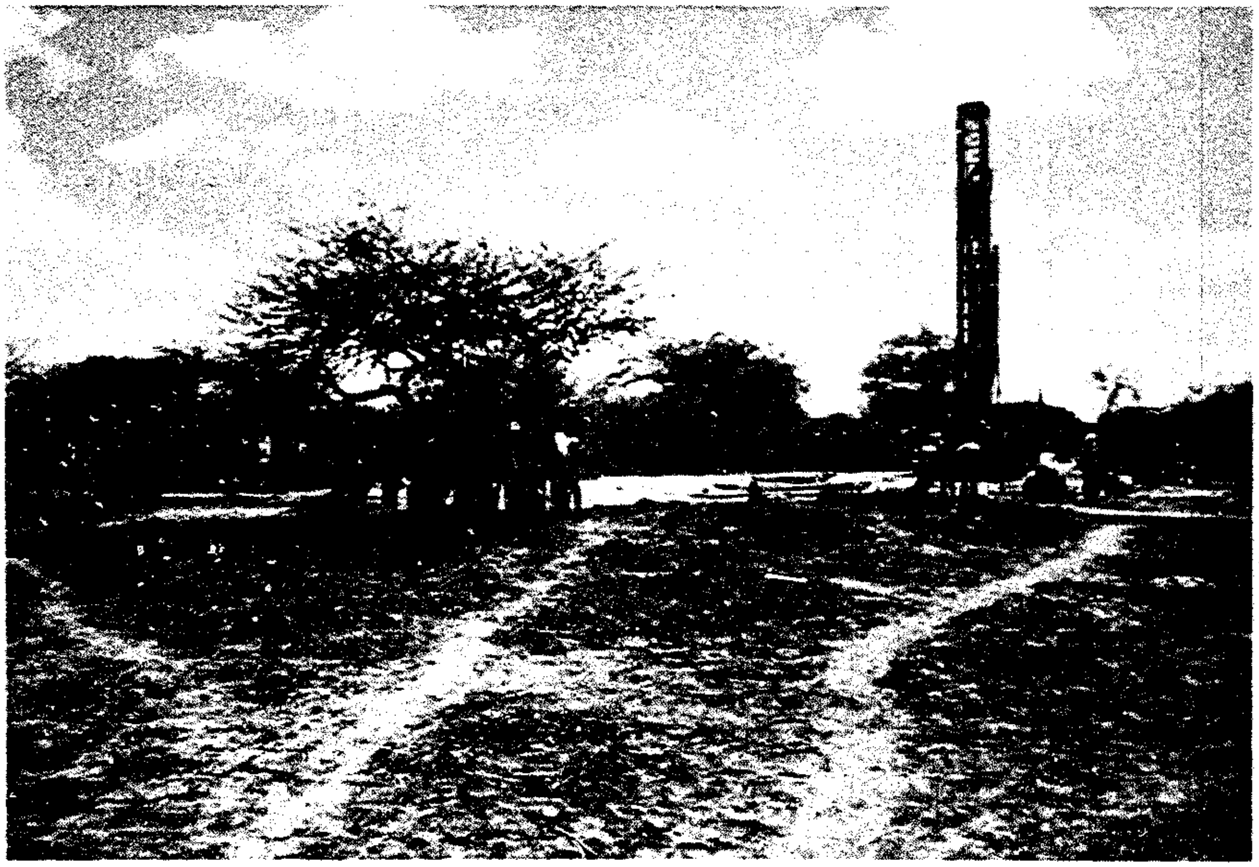
SOMALI DEMOCRATIC REPUBLIC
MINISTRY OF MINERAL AND WATER RESOURCES
Water Development Agency

COMPREHENSIVE GROUNDWATER DEVELOPMENT

Project 104



FINAL REPORT

VOLUME I

General Activities

LOUIS BERGER INTERNATIONAL, INC.
ROSCOE MOSS COMPANY

MARCH 1985

VOLUME I

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

We wish to thank the staff of the Water Development Agency and the Ministry of Mineral and Water Resources for their assistance in the preparation of this report. Photos used in the text were by Wes Glessner.

This report is dedicated to the memory of Ken Sanders, driller, who died while working on the Comprehensive Groundwater Development Project.

1. INTRODUCTION

1. INTRODUCTION

In Somalia, the scarcity of dependable water supplies for the rural population and their livestock is the most serious constraint to continued economic development and the most vital problem in efforts to provide better human services. Thus, the Government of the Democratic Republic of Somalia, with assistance from USAID, established and funded the Comprehensive Groundwater Development Project (CGDP). The firm of Louis Berger International, Inc., in association with the Roscoe Moss Company (hereafter referred to as LBI/RM), was contracted to provide technical assistance to the Water Development Agency (WDA) under the Ministry of Mineral and Water Resources (MMWR). Field operations began in July of 1981.

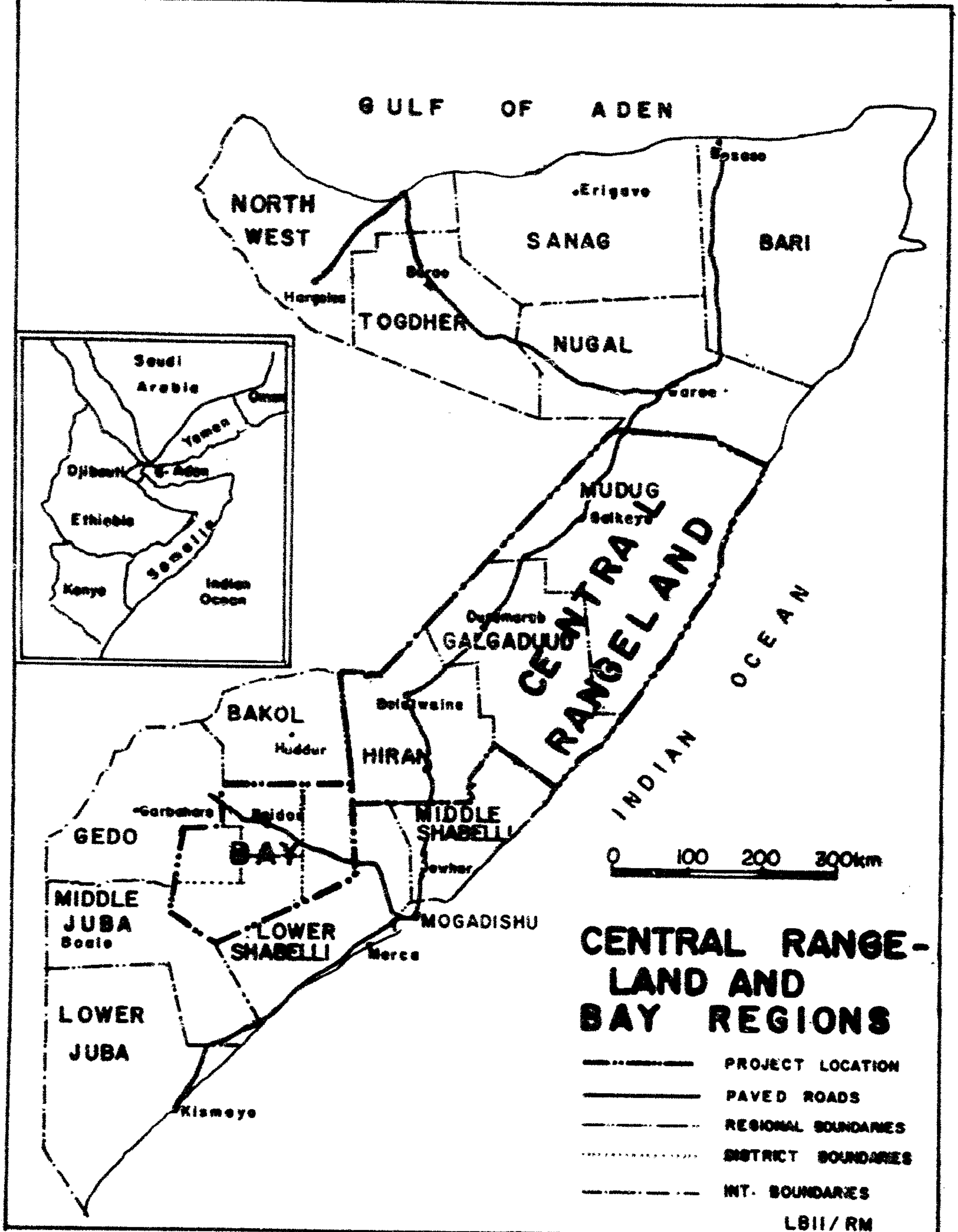
The overall purpose of the CGDP was to strengthen the WDA's capability to install, operate, and maintain rural water supply systems, and the specific goal was to develop the water resource base in the designated priority areas of the Bay, Hiran, Galgadud, and Mudug Regions (Figure 1.1). Thus, technical and material assistance was primarily focused on the installation of a specified number of wells for domestic and livestock use in each of these regions in support of ongoing integrated rural development projects. The CGDP was designed to be integrated with those projects, namely the Bay Region Agricultural Development Project (BRADP) and the Central Rangelands Project (CRP), and to rely upon general institutional and specific commodity support from those projects.

In order to achieve the purpose and goals of the CGDP, four primary objectives were defined in the LBI Inception Report (August, 1981). They were:

1. to conduct preliminary data collection;
2. to undertake an exploration and production program;
3. to provide institutional support to the WDA and the MMWR; and
4. to establish an ongoing data collection system.

1.1 Report Objectives

It is the primary purpose of this report to summarize project activities from the beginning of the LBI/RM contract to the present (July, 1981 - June, 1984). This report is divided into two volumes and an Appendix. Volume I is "General Activities of the CGDP," which provides a summary of activities in well production, data collection, and institutional support. Volume I also contains sections on sociology, economics, and environmental assessment, all of which have been given in-depth treatment under the project.


GULF OF ADEN
NORTH WEST
Hargeisa
Burao
TOGDHER
SANAG
Erigavo
BARI
Bosaso
NUGAL
Garoe
MUDUG
Galkayo
CENTRAL RANGELAND
GALGADUUD
Dusamareb
INDIAN OCEAN
BAKOL
Huddur
HIRAN
Beletwaine
MIDDLE SHABELLI
Jowhar
GEDO
Garbahare
Baidoa
BAY
MIDDLE JUBA
Boale
LOWER SHABELLI
Merca
MOGADISHU
LOWER JUBA
Kismayo
Saudi Arabia
Oman
Yemen
Djibouti
G. Aden
Ethiopia
Somalia
Kenya
Indian Ocean
0 100 200 300km
CENTRAL RANGE-LAND AND BAY REGIONS
PROJECT LOCATION
PAVED ROADS
REGIONAL BOUNDARIES
DISTRICT BOUNDARIES
INT. BOUNDARIES
LBII/RM

Volume II is "Hydrogeology" and contains a summary of information relating to the occurrence and distribution of groundwater. Most project activities have been undertaken in the Bay Region and therefore the report will prove valuable for future groundwater development in the Bay Region. Limited drilling has taken place in the Central Rangelands and the results are also included in the report.

The appendix contains data sheets including sketch maps of well locations, pumping tests, lithological profiles, electrical logs, well construction, and water quality. Water quality data includes not only CGDP wells but other selected locations.

Volume I is divided into nine chapters including this Chapter I "INTRODUCTION."

A brief summary of the succeeding chapters is provided in the following paragraphs.

1.2 Wells

The construction of wells has been the primary focus of the CGDP. Drilling has been undertaken both in the form of exploratory drilling and production drilling. Exploratory drilling was undertaken in areas where, because of limited information, it was difficult to predict the probability of success. Production drilling was undertaken when sufficient data was available to provide a reasonable chance of obtaining water. This chapter also provides a description of well construction techniques including the construction of distribution systems.

1.3 Data Collection

Data collection has been undertaken throughout the project life. Data collection is an ongoing activity primarily in hydrogeology but also in other diverse fields including socioeconomics.

1.4 Institutional Support

Chapter 4 provides a description of institutional support provided to the WDA and MMWR. Training has been the keystone of this support as all counterpart personnel have received training in selected subject areas. Institution building has also provided support in the fields of financial and planning management, warehousing, vehicle maintenance, and water quality analysis at the MMWR laboratory.

1.5 Sociology

Chapter 5 provides a resume of sociological findings. Much of this work was accomplished early in the project and then utilized during project implementation to assure community participation in well construction and maintenance activities.

1.6 Economics

In Chapter 6, the economics of water well development are provided. Project costs are detailed and shown according to the various components involved.

1.7 Environment

Chapter 7 provides a summary of environmental considerations present in groundwater development and actions to mitigate any possible deleterious effects.

1.8 Recommendations and Conclusions

Finally, Chapter 8 provides a summary of the key conclusions and recommendations for future activities of the WDA.

2. WELLS

2. WELLS

The primary focus of the CGDP has been on the construction of wells. The wells have been of two types, exploratory and production. The drilling of the wells required the development of techniques based on the available equipment and the particular geologic conditions encountered. Production wells, after the completion of drilling and pump testing, were equipped with a distribution system.

2.1 Exploratory Wells

In the Bay Region, exploratory wells were undertaken primarily during the first year (February, 1982-January, 1983) of drilling activities. A total of 26 exploratory wells were drilled throughout the Bay Region in areas where the geology was little known, and, in most cases, where there was an expressed need for water wells. The results were published in the "Exploratory Report for the Bay Region." This report provided probabilities of success for finding groundwater in relation to the various types of geology. Although low probabilities of finding water were indicated for the southern part of the Bay region underlain by crystalline rock, it was an area of high water need as determined by the BRADP authorities; therefore, further exploratory wells were undertaken at specific sites.

In the Central Rangelands, drilling was not begun until March, 1983, as management preparations were not completed by the CRP until that time. Since the geology of the Central Rangelands was broadly known although little information on the hydrogeology of specific areas was available, drilling of an exploratory nature was begun. The sites were chosen within areas where the CRP had undertaken the development of range management plans. Drilling in the Central Rangelands was beset with problems. The drilling proved difficult from a technical perspective and ultimately security problems, resulting in the killing of an RM staff driller, caused the suspension of activities in the Bulo Berti district of the Central Rangelands in December of 1983. A total of six wells were drilled in the Bulo Berti district. In May of 1984, drilling was begun in the Hobbio district and one well was completed at the time of this report.

2.2 Production Wells

Whenever water was found in sufficient quantity and quality, the borehole was completed as a production well. Sufficient quantity was considered to be a minimum of about 10 cubic meters per day or the amount that a hand pump could produce. Sufficient quality required a specific conductivity of less than 3500 umhos for human consumption or 10,000 umhos if the well was to be utilized for stockwater purposes.

In practice, whenever a well yielded sufficiently to justify the construction of a storage system, which was typically 45 cubic meters, a motor pump was installed. Otherwise a hand pump was installed.

Production wells were equipped with either PVC or steel casing and screen. The screen was installed in appropriate aquifer zones. Steel casing was required for all deep wells, usually exceeding 50 meters, while PVC casing was utilized in shallow wells. In some cases, where the rock was stable, the lower part of the borehole was not cased but left "open hole."

The total production wells completed by the end of July, 1984, in the project areas was 32 wells (30 in the Bay Region and 2 in the Central Rangelands). Of these, 20 had been equipped with pumps and the remainder were scheduled for pump installation, and, if warranted, the construction of a distribution system (see Table 2.1.).

The success rate of 30 production wells out of a total of 69 boreholes (46%) was low because of the need for exploratory drilling. In areas where exploratory drilling had yielded conclusions on drilling probabilities of success, such as the Limestone Plateau of the Bay Region, the production well rate was good (74%). A comparison of production wells by area is given below.

	Boreholes	Production	%
Bay Region			
Limestone Plateau	35	26	74
Basement Complex	27	4	15
Central Rangelands	7	2	29
Total	69	32	46

In addition to the CGDP wells indicated in Table 2.1, other wells were also completed with the assistance of project personnel. In the Bay Region, three wells were constructed to assist road construction by the WDA under contract to the Ministry of Transport at Foolfayle, Qansax Dheere, and Ceel Muri. Also, during start-up activities at the beginning of the project while Phase I data collection was in progress, four wells were constructed in Mogadishu. These wells were located at the Bendair Childrens and Maternity Hospital, the Presidential Compound, the American School, and a municipal site in Mogadishu. In total, the LBI/RM staff has assisted in the construction of 39 production wells during the three-year life of the project.

Table 2.1

CGDP WELLS

Well No.	Location	Date Completed	Total Depth (m)	Production Well	Pump Type
1	Bonkay	4/2/82	19		
2	Bonkay	27/2/82	201	x	(Monitor well)
3	Bonkay	13/4/82	160	x	M
4	Tugerew I	11/6/82	42	x	H
5	Gasarta	21/3/82	42		
6	Waraji I	23/3/82	80		
7	Waraji II	25/3/82	39		
8	Tugerew II	29/3/82	48		
9	Bur Halab	30/3/82	32		
10	Sarman Dheere	27/4/82	84	x	M
11	Min. Agric. Cmpd	2/6/82	137	x	
12	Hareero Jiifo	7/7/82	166	x	M
13	Shabelle Dugsilow	13/7/82	172		
14	Warta Jaffay	3/8/82	91		
15	Qansax Omane	19/8/82	174		
16	Taflow	16/8/82	153	x	M
17	Robay Gaduud	6/10/82	138	x	H
18	Gaduudo Dhunte	6/10/82	73	x	M
19	Buulo Fuur	14/9/82	94		
20	Durei Ali Galle	14/10/82	116	x	H
21	Min. Agric. Cmpd		42	x	M
22	Buulo Gaduud	5/1/83	189		
23	Kurman	22/1/83	148	x	H
24	Yaaq Braawe	26/1/83	10	x	H
25	Dodole	13/1/83	24		
26	Shiidalow I	20/1/83	67		
27	Shiidalow II	22/1/83	80		
28	Bur Akaba I	25/1/83	54		
29	Bur Akaba II	26/1/83	24		
30	Bur Akaba III	1/2/83	30		
31	Bur Akaba IV	2/2/83	63		
32	Bur Akaba V		89	x	H
33	Bur Heibi I	10/3/83	27		
34	Bur Heibi II	22/2/83	73	X	H
35	Bur Heibi III	23/2/83	60		
36	Bur Heibi IV	15/3/83	25		
37	Bur Heibi V	15/3/83	26		
38	Bur Heibi VI	16/3/83	36		
40	Ls. Depression	23/2/83	32		
41	Dolondole		166	x	
42	Buulo Fuur II	3/5/83	130	x	M

Table 2.1 (cont.)

Well No.	Location	Date Completed	Total Depth (m)	Production Well	Pump Type
43	Aborey I	3/5/83	120		
44	Afar Irdood	6/83	174		
45	Min. Agric. Cmpd		120		(Monitor well)
46	Qansax Dheer	5/83	103	x	
47	Awshiini	31/7/83	143	x	M
48	More Ari	28/6/83	102		
49-1	Maxas (Jeejo)	9/9/83	190		
49-2	Maxas (Jeejo)	15/10/83	180		
50	Bonkay Seed Farm	22/9/83	200		
51	Mintaano	11/83	132	X	H
52	Maleel	11/83	130	x	M
53	Aborey II	19/12/83	133		
54	Isgeed	19/12/83	150	x	H
55	Marti Moog	23/1/84	147	x	H
56	Jimcaada Dheen	3/3/84	41		
57	Hagarka	3/3/84	154	x	H
58	Bur Akaba VI	25/3/84	27		
59	Shawka	18/3/84	138		
60	Kannanax	27/3/84	16	x	
61	Hubay	5/4/84	152	x	
62	War Asha	29/4/84	201		
63	Bonkay Seed Farm	25/4/84	153	x	
64	Buulo Yussef		85	x	
65	Aborey III	18/5/84	210		
66	Buulo Hawo		144	x	
67	Wargoleh		252	x	
68	Dumbal Aalin		122	x	
69	Tagaal		92	x	

x Indicates production well (quantity and quality) of water sufficient for rural water supply needs) that has been cased and screened.

M Indicates motorized pump installed.

H Indicates hand pump installed.

It was originally planned, as indicated in the Inception Report, that at least 72 wells would be drilled, of which 48 would be production wells, during the three-year life of the project. These goals were not met for several reasons, including delays in commodity procurement, fuel shortages, and security problems.

Long delays in procurement of required commodities prevented drilling to proceed as scheduled. Initially, available project funding was insufficient to begin drilling as even basic requirements, such as drill bits, were not stockpiled. Support equipment, such as water trucks and fuel trucks, were insufficient to operate three drilling rigs at the same time. No pumps for well testing were available. When funding became available, $4 million in commodities were specified in May, 1982, but delivery took from 9 to 21 months. The final delivery of the last item on the May, 1982, order was not delivered to Somalia until February, 1984.

Fuel shortages have been a continual problem throughout the life of the project. While it was recognized and so stated in the Inception Report that Somalia had a past history of fuel shortages, assurances were given that the CGDP would receive priority in obtaining fuel. However, the project never operated more than three consecutive months with a complete supply of fuel. Usually, fuel was rationed in less than sufficient quantities, and, at times, the project was completely stopped for having exhausted all supplies.

Finally, security issues reduced project efficiency more than originally expected. The killing of an RM staff driller in Bulo Berti district caused the suspension of drilling in that area. Other incidents, of less magnitude but nonetheless significantly affecting project efficiency, included Ethiopian jets overflying Baidoa, difficulties in making arrangements for travel permits and providing armed guards to work in certain areas, and the occasional disruption of activities because of priorities of the Somali military.

2.3 Water Storage and Distribution Systems

After completion of a production well, a distribution system was designed which often required a storage system. The design of such systems, the selection of equipment and materials, and the actual construction process were all issues which required the development of coordinated planning. LBI engineer David Boggs and WDA engineer Mohamed Burale Guled undertook the development of the civil works systems.

2.3.1 Pumping Equipment

Pumping equipment consisted of two types, diesel-powered pumps and hand pumps.

Diesel-powered pumps have been supplied by Mono Pumps, Ltd. of Great Britain. The pump is a positive displacement helical rotor, line shaft model. It is driven by a twin cylinder, air cooled, diesel engine, using a V-belt and centrifugal clutch. This combination results in a simple, efficient, low cost operation and maintenance system capable of producing approximately 11.4 m^3/hr (50 gpm) at 150 meters total dynamic lead.

Handpumps were procured for use in small villages where demand is low or in boreholes that fail to produce sufficient water for the diesel-powered pumps. The handpump, supplied by Robbins and Meyers of the United States, is of helical rotor design. It is known for long life, low cost maintenance, ease of operation, and acceptability by persons in rural areas. These handpumps were stocked in two models. The Robbins and Meyers IV12 is designed to pump .9 m^3/hr (4 gpm) from 45 meters depth and the 2V12 is designed to pump .9 m^3/hr (4 gpm) from 90 meters.

A sketch of a diesel-powered pump is shown in Figure 2.1 and a hand powered pump in Figure 2.2.

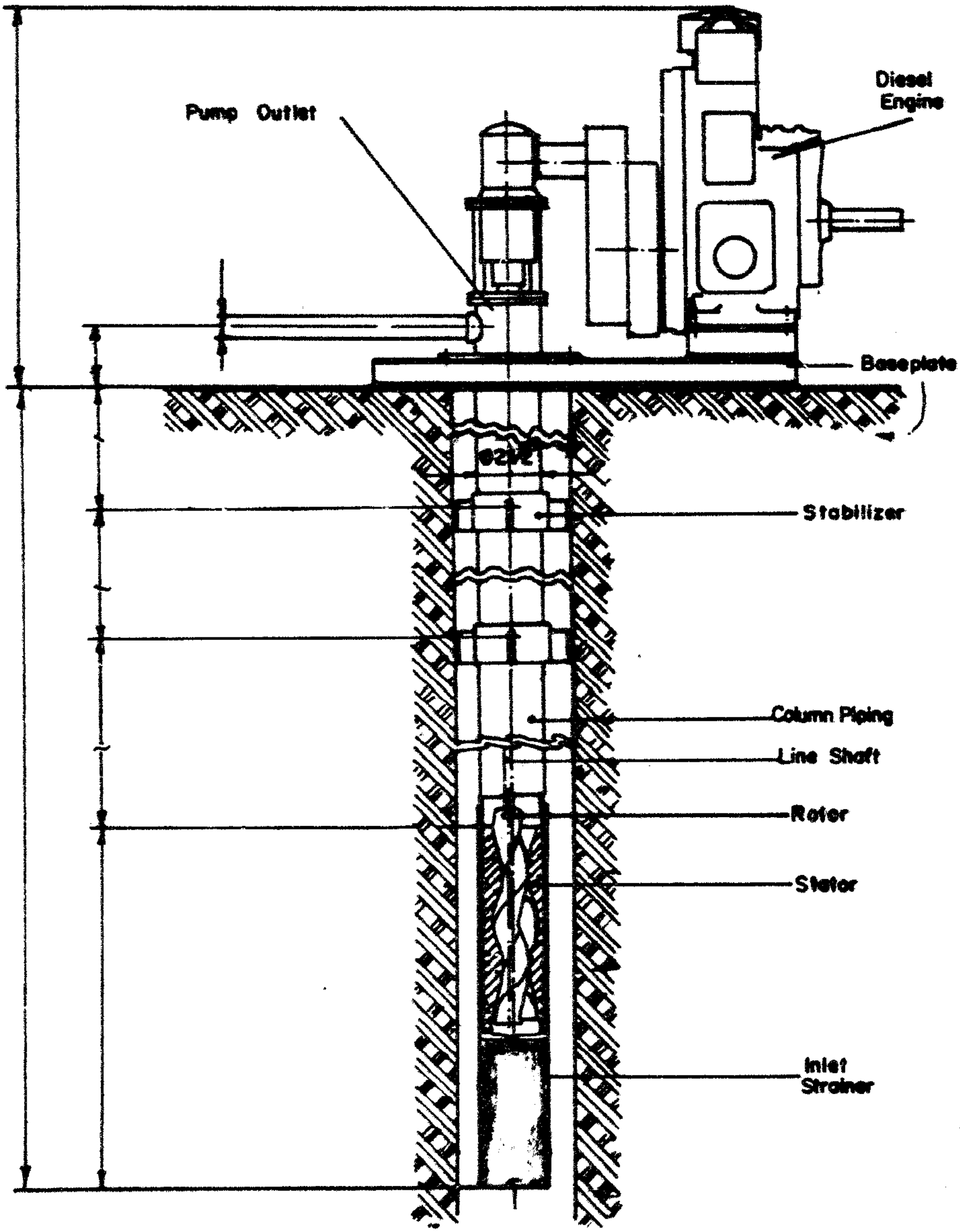
The type of pump installed at any given location was dependent upon the water yield of the well and the static water level. Those wells with high yields received motorized pumps and large storage and distribution systems, while low yield wells were equipped with hand pumps.

2.3.2 Storage Requirements

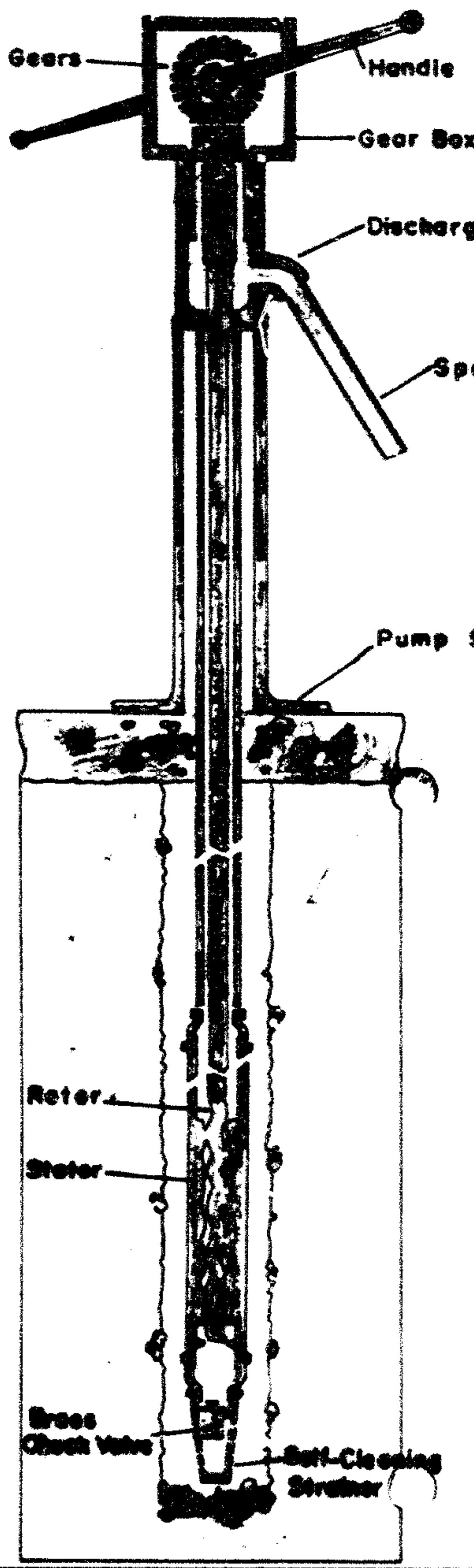
At high-yielding wells, it was necessary to provide a storage reservoir to maintain a reserve in the event of equipment failure or fuel shortage. Based on limited information, estimates of human and animal population for the Bay Region were made to determine a daily water demand at each site. Surveys were also made of the nearest pump, permanent spring, or all-season reservoir at each site, in order to estimate the service area that each well might encompass. This allowed a rough estimate of potential water demand for each well site.

These surveys revealed that during periods of severe drought, people and livestock from very large areas could rely on these wells as the only supply of water. At most sites, potential service areas ranged from 80 to 700 square kilometers. By applying available water consumption rates and potential service populations, it was found that a storage volume of 45 to 100 m^3 was required to provide a two-day reserve of water. Two days were considered to be the maximum transportation time for a maintenance crew or a fuel delivery vehicle to reach a well site. For these reasons, it was decided to provide a water storage reservoir of 45 m^3.

MONO DIESEL POWERED PUMP



LBII / RM



TYPICAL HANDPUMP INSTALLATION

"Rated at 1 m^3 per hour at 90m depth"

LB11 / RM

The water storage reservior was designed to be constructed above ground, with sufficient elevation for water to gravitate to the watering points. The alternative of providing below-ground or ground-level storage was rejected due to the likelihood of contamination by the introduction of unclean vessels into the reservoir.

2.3.3 Selection of Materials

Construction materials were selected based on cost, durability, compatibility with local skills, speed of construction, and availability of local materials. Several alternatives of materials were considered: masonry, fiberglass, and steel. Cost estimates were made for each alternative, and, for material only, the results were found to be as follows:

1.	Masonry	sh 4,000/m3
2.	Fiberglass	11,250
3.	Locally-made steel tanks	10,000
4.	Imported steel tanks	8,000

The decision was made to use masonry tanks because the masonry tank is more economical than any of the other alternatives considered, masonry construction is more compatible with the skills of local masons, and repairs can be made more easily on masonry structures by local workers. The use of steel tanks was not considered economically viable because of the highly corrosive water found in Somalia which limits the useful life of steel tanks. The disadvantage of masonry construction was that the construction time required is greater than that for other types of tanks.

The type of piping used was limited to three choices: galvanized steel, polyvinyl chloride (PVC), or polyethylene (PE). Although plastic (PVC and PE) pipe is less costly, it is not in common use in Somalia. Plastic pipe must be buried for protection from weathering, vandalism, and animal traffic, whereas steel pipe can be laid above ground, if necessary.

It was decided to use both galvanized steel pipe and polyethylene pipe. In those areas where trenches could be dug easily, polyethylene pipe was used. In rocky areas, where trenching was not possible, galvanized steel pipe was used.

2.3.4 System Layout

The typical layout for a motorized-pump well installation consists of the pump foundation with the pump discharging to a 45 m3 masonry water storage tank. From the storage tank, water is distributed by gravitation to two or more livestock watering troughs via 1 1/4-inch diameter galvanized steel water pipe, and to a fountain with five to twelve spigots for people.

The system layout varies according to village preference, topography, and water quality. In general, livestock watering troughs are located at a distance from the village, in areas where forage material is available and in such a way that wastewater drains away from the well site to a sump pit which is dug to receive this wastewater. In most cases, the storage tank is located at the highest elevation in the immediate area with drinking fountains located near the village. Drainage ditches, livestock troughs, and fountains are protected from animal intrusion by thorn bush fencing. In wells where salinity content of the water is above the accepted limit of 3500 umhos, drinking fountains are not constructed. The exact system layout thus varies somewhat between sites. A typical system is shown in Figure 2.3.

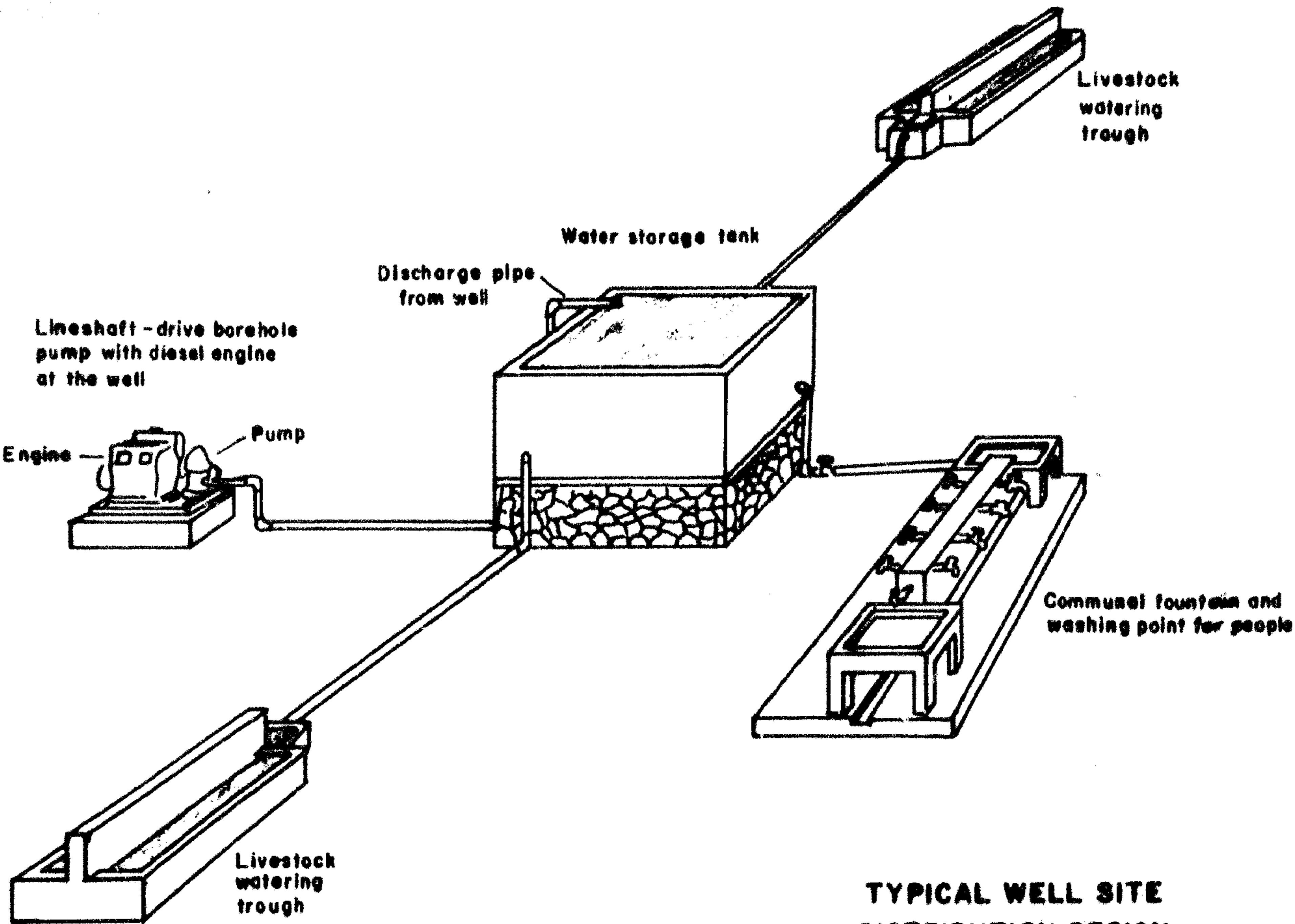
2.3.5 Training

Training of WDA staff consisted of both formal classroom instruction and on-the-job training. During the rainy seasons, when access to sites became limited, classroom training was provided by LBI technical staff to WDA personnel. In the construction of civil works, however, the majority of the training was on-site. During the construction of the first major civil works at the village of Sarman Dheere, both the LBI engineer and WDA civil engineer were present full-time in order to assure that design specifications were being followed and proper construction techniques were applied.

Masons were introduced to new concepts such as use of line levels, testing of sand for organic content (with 5% sodium hydro-oxides), silt content, concrete slump testing, and preparation of correct concrete mixtures. Plumbers were introduced to the use of teflon tape for making pipe connections, use of modern pipe threading equipment, and use of lubricating oil in the pipe threading process. After the completion of the first major civil works site, the construction crew was split into two crews, operating independently, with reduced need of outside supervision.

2.3.6 Construction Personnel

Personnel required for the construction of civil works systems consisted of three teams. Two teams were involved in motorized well distribution systems while a third team installed hand pumps. Figure 2.4 shows an organizational chart for the Bay Region consisting of seven WDA personnel for each of the motorized-well teams.



TYPICAL WELL SITE
DISTRIBUTION DESIGN
WITH MOTORIZED PUMP

CGDP CONSTRUCTION ORGANIZATIONAL CHART

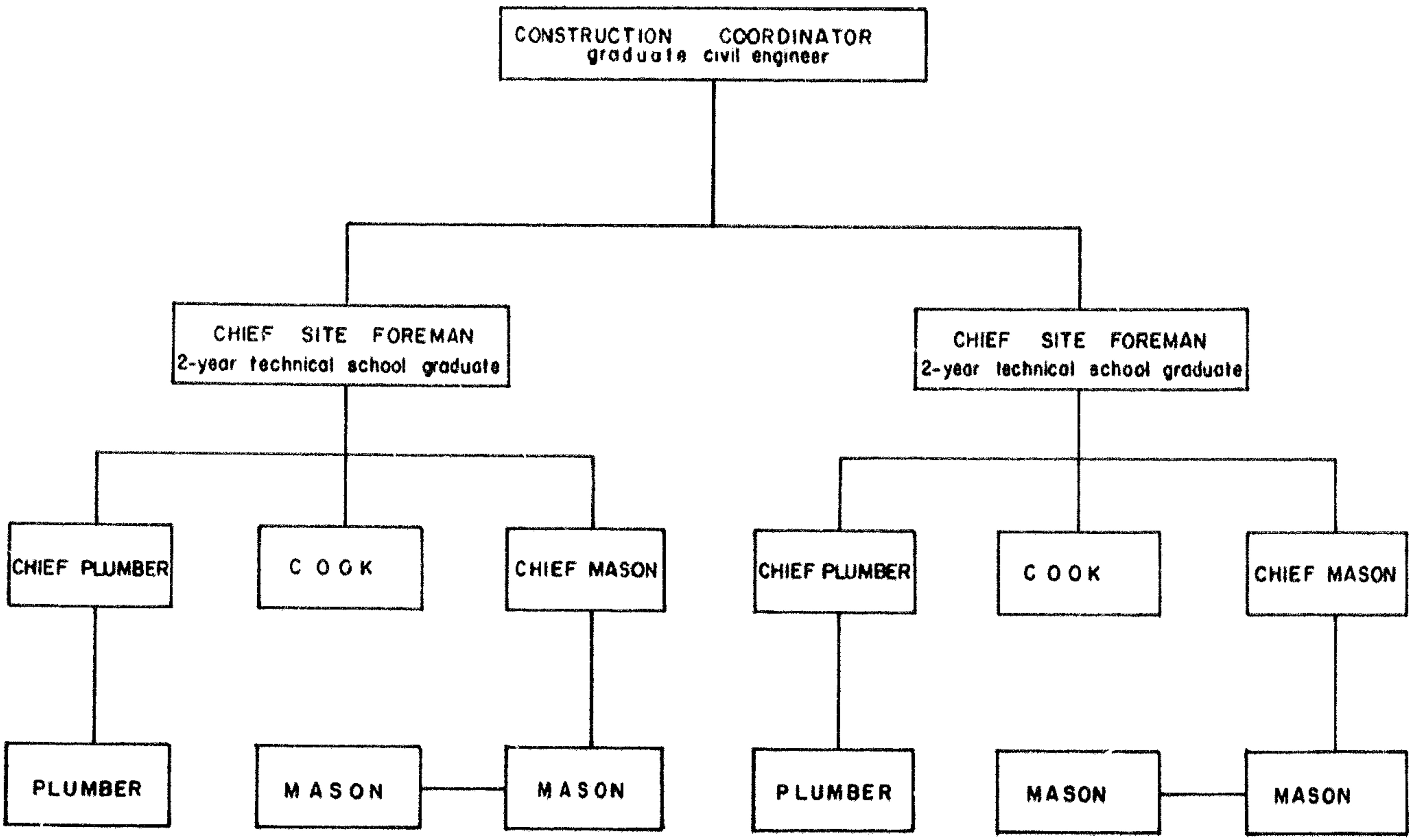


Fig. 2.4

In addition to the seven WDA staff, each village was expected to provide fifteen unskilled laborers to assist in the construction process on an "Iska Wax U Qabso" (self-help) basis. The requirement that the village provide workers for the construction process was always agreed to beforehand, but, in practice, the process varied between villages.

Depending upon the cooperation and influence of the village leaders and the season, the number of villagers actually available for working was variable. This ultimately affected the speed of completion of each construction site. During periods of planting or harvest, village manpower was usually in short supply. In many cases, the village laborers expect to be paid by the village water committee. Sometimes the water committee did not keep its promises for payment, and laborers refused to work. The "self-help" process results in construction that often proceeds slowly. However, in the long-term it is expected that the self-help process will contribute to better maintenance for the water distribution system.

2.3.7 "Crash" Program of Pump Installation

During January through April, 1984, Somalia experienced a severe drought. In an attempt to mitigate the effects of the drought, it was decided to pour foundation pads and install handpumps at all potential production wells. A temporary steel adaptor plate was fabricated to allow a handpump to be installed at wells where a motor-driven pump would eventually take its place. This program helped to relieve some of the problems of drought, but it also slowed the completion of the major civil works due to the drain on manpower and transportation facilities. In several cases, the hand pumps will eventually be replaced with a motorized system if warranted.

By July, 1984, a total of 11 hand pumps and 9 motorized pumps were in operation in the Bay Region. Construction crews were continuing their work although motorized pump systems, which require two months to complete, cannot keep pace with the drilling process. Since the WDA does not have sufficient staff with the requisite technical background to expand the construction crews, other alternatives are being explored. These include contracting with independent construction firms or utilizing fiberglass storage tanks. The latter offers the ease of prefabricated construction which would cut construction time. Fiberglass tanks are being manufactured by a new Somali firm and, at the time of this writing, their feasibility is being explored further.

2.4 Well Construction Techniques

The objectives of the drilling program during the production phase of operations were:

1. To utilize the methodology developed during the Exploratory Phase and develop the most efficient use of available equipment.

2. To improve completion techniques for drilling production wells and provide continued training of the WDA crews.

The project was provided with three Ingersoll Rand TH-60 drilling rigs. The rigs were equipped with 600 cfm, 250 psi Compressors and Gardner Denver 15½-inch by 8-inch mud pumps. The equipment was adequate for constructing wells utilizing 8 inch casing and for pumping depths up to 150 meters. In addition, a cable tool rig provided by the WDA was sometimes used in particular circumstances.

2.4.1 Drilling Techniques

The drilling techniques were based upon the experience gained in the Bay Region during the Exploratory Phase of the project. In most cases, the Bay Region wells were drilled in consolidated formations, such as limestone and sandstone with the down-hole-hammer method. When unconsolidated formations were encountered, the down-the-hole-hammer was replaced with a tri-cone bit. In both cases water and drilling foam were injected to extract the drill cuttings. In karst limestone formations, where there were no returns of cuttings, the hole was reamed with a 15½-inch bit and 12-inch casing set through the lost circulation zone. A 10-inch bit with a stabilizer was then used to complete the open borehole. If adequate quantity and quality of water were found, the borehole was cased with steel casing and slotted screen (slotted casing) in the deeper wells and with PVC casing and slotted screen in shallow wells of 50 meters or less.

In some limestone areas, the rock was found to be hard and generally stable enough to remain uncased. The initial boreholes were drilled with a 7 7/8-inch bit and then reamed to 10 or 12 inches using a stabilizer. Eight-inch casing was then installed to serve as a pump chamber. Below this casing the borehole was left open.

In a few wells where gravel pack was required, the annulus was limited to 3½ inches due to the 12-inch diameter limitation when drilling with air. In aquifers with good transmissivity, this is an adequate gravel pack thickness. In low yielding aquifers consisting of fine silty materials, similar gravel pack thickness could be used but particular attention to size of screen opening and size of gravel pack material would be required. The gravel obtained for use in packing wells is only available at a few scattered locations in Somalia. Particular attention was necessarily directed to gravel procurement, as it was an important factor in determining well yields.

Mud drilling was used almost exclusively in the Bulo Berti area. The formations in this area are primarily unconsolidated residual clays with a high sand content, gypsum and weathered sandstone. At the location of Aboorey well 1, a 50-meter-thick layer of coarse sand was encountered from 60 to 110 meters. At 120 meters a complete loss of circulation caused the mud to drain into a cavernous area and completely collapsed the well. Several attempts, using a thicker mud to recover the hole, were futile and a new well was drilled at the Aboorey III site. This well was completed to 210 meters by using mud and with no loss of circulation.

2.4.2 Rock Characteristics

During drilling operations various types of rock were encountered as described in the "Hydrogeology" chapter. The technical characteristics of these rocks in relation to drilling are described in the following paragraphs.

1. Limestone

This rock is generally hard and dense enough to allow air rotary drilling and completion without casing. The top layers may be karstified to a depth of several tens of meters making drilling with mud impossible. Drilling with air as the circulation medium and using an air hammer is fast where the limestone does not contain cherty layers. The middle Baidoa Limestone is overlain by caliche and by terra rossa, which have a tendency to fall back into the hole and plug drilling bits. This problem also occurred in the Qansax Dheere area at well numbers 6, 9 and 20).

2. Marls

These rocks were encountered in the Baidoa Formation and in the Anole Formation, with various degrees of carbonate content. Marls may become very soft in contact with drilling fluid and cave into boreholes, requiring casing while drilling. Problems in boreholes number 13 and 14 in the Anole Formation were due to swelling of clay and caving of soft marls.

3. Clays and Shales

These occur mainly in hard shale interlayers in limestone of the Baidoa Formation with no immediate tendency to swell. Clay and shale beds in the Anole Formation, however, are soft and cause more potential risks to the borehole.

4. Residual Clay

Clays with various degrees of silt and sand content occur over large areas of the Limestone Plateau and in the patches of limestone that overlie the basement. While in contact with water, these clays begin to swell, making vehicle access to the drilling sites impossible and closing the boreholes after the completion of drilling. Clay swelling and caving negatively affected the irrigation well No. 2 of the Bonkay Farm.

2.4.3 Recommended Procedures

Drilling and completion procedures developed during the exploratory and production phases are described below. These procedures were developed over a wide variety of geological conditions:

1. A surface string should be cemented in place. This must be steel pipe so that drilling may ensue inside the pipe.

2. The diameter of the surface casing should be no less than 14 inches.

3. A borehole should extend to a depth of 10 meters below the aquifer.

4. Reaming should be to a 12½-inch diameter and as deep as the TH-60 will penetrate and still permit cuttings to reach the surface.

5. Water quality samples should be taken for chemical analysis as each aquifer is reached, preferably before the introduction of foam.

6. A static water level should be taken each morning before drilling begins.

7. A casing schedule should be approved by the assigned hydrogeologist before casing the well.

8. An 8-inch string of casing should be lowered until the screen is opposite the water zone as determined by the hydrogeologist from the electric log. The hole diameter should be logged prior to introduction of the casing if caliper logging equipment is available.

9. The temperature of the water and the electrical conductivity should be taken as each aquifer is reached.

10. Compressed air should be used to circulate the water in order to estimate the available water supply as drilling encounters each aquifer.

11. For wells completed in unconsolidated materials, a formation stabilizer or gravelpack should be introduced between the borehole and the casing up to within 20 meters of ground surface. A gravel makeup pipe should be installed.

12. A sanitary seal should be set above the gravel pack to ground surface and capped by a one-meter square cement pedestal which slopes away from the casing.

13. In areas where large solution cavities are encountered a cable tool drill rig should be used.

14. For deep wells, where the aquifer is at considerable depth and water quality is saline and potentially corrosive, thick walled PVC casing with screw joints and couplings should be used. Shallow wells in corrosive areas should use the thin-walled PVC casing held together by epoxy cement. Setting time for cement is critical and should be maintained at least 15 minutes.

15. It is preferable that a well should not be attempted until all supplies are at the site, then continue until completed.

16. A minimum amount of time should be allowed to pass between completion of a well and equipping it for production to prevent calcium carbonate or other encrustations from plugging up the screens.

17. Development to remove fines from the well bore and the aquifer in the vicinity of the well should be made on the well when completed during which pumping water levels should be taken and specific capacity values calculated. The well should be pumped at a higher than anticipated rate of production. When no further improvement in specific capacity of water clarity is made, the pump test should be stopped.

18. Appropriate well development techniques should be used on every well.

3. DATA COLLECTION

3. DATA COLLECTION

Data collection has been a major component of the CGDP. The objectives were, first, to conduct a preliminary phase of data collections affecting groundwater development in Somalia. Secondly, the project proposed to establish an on-going system of data collection so that this component would become institutionalized within the MMWR and WDA.

3.1 Preliminary Data Collection

Preliminary data collection took place under three components; the undertaking of a general nationwide survey of published materials, a detailed study of project priority areas, and the completion of an exploratory drilling program.

3.1.1 Literature Review

The first activity undertaken for data collection was a general resource survey of groundwater related literature for Somalia. A literature search was conducted of all pertinent documents and reports on the groundwater of Somalia. This literature was far from extensive, although some areas have been studied in detail. A list of referenced literature is included in the "Bibliography" Chapter. One study conducted by the UNDP in 1973, entitled "Groundwater in the Somali Democratic Republic", provides data related to many groundwater sources. All available data from earlier studies were incorporated into this report, including well logs, water quality analysis, and location of wells. Other documents published since 1973 have been collected when available, or at least located for perusal and consultation. Unfortunately, however, there were some reports identified that were unavailable. Also many drilling reports of wells completed previous to the CGDP in Somalia have been lost and are irretrievable.

The second activity undertaken was a standardization of forms for data compilation. This activity was instituted within the WDA with support from GTZ, the German technical assistance organization for development. The forms were extensive, covering all phases of water resource development, but, unfortunately, were inappropriate as few of the forms could be completed entirely. The CGDP has been preparing data collection forms as shown in the Appendix of this report.

3.1.2 Detailed Study of Priority Areas

A detailed study of the Bay Region was completed in early 1982. A preliminary field survey was undertaken of existing wells and water points, but, because of the lack of hydrogeologic measuring equipment, little information other than the location of wells was obtained. The only groundwater literature produced on the Bay Region was a report on the "Bur area", an area within the Bay Region of limited hydrogeologic potential (Idrotecneco, 1975).

In the absence of significant data on which to base the exploratory program, exploratory drilling was conducted in areas where a water demand existed. The exploratory program was thus designed not only to provide a representative coverage of the Bay Region but also to determine the availability of water in areas where identified demand exists. A site selection process was developed, in cooperation with the BRADP, which answered the needs of exploration as well as those of water provision.

At the time that studies of the Bay Region were underway, the CRP had not begun. It was not until early 1983 that priority areas of the CRP were established. Therefore, detailed studies of the CRP were not undertaken by the CGDP. It was considered that management plans developed by the CRP would provide the data collection required to determine well sites based on water needs.

3.1.3 Exploratory Drilling Program

The exploratory drilling program was completed in January, 1983. A total of 25 boreholes were completed along with electric logs. All data collected during the preliminary collection program were included in the "Exploratory Report for the Bay Region". In addition to the results relating to hydrogeology, the report included water quality analysis, drilling technology, and socioeconomic studies. Only minor data on pump testing were included as the necessary equipment was not available until later in the project.

3.2 On-going Data Collection

An on-going data collection program was established to collect and collate data generated during the production phase of drilling. Data collected included drillers reports, geophysical logging, pump testing, and water quality analysis. All such data have been collated and are reported in Volume II of this report. Maps and reports have been updated and results analyzed to produce the recommendations and conclusions provided in Volume II.

A separate economic report was produced in February, 1984, and is resumed in this report. The effectiveness of the fee collection system was analyzed in the Economic Report and found to be adequate in meeting the recurring costs of well operation and maintenance.

It was originally planned to evaluate the use of completed wells in a complete and systematic manner. However, since wells under the CGDP only first became operational with the arrival of pumps in late 1983, only preliminary observations on the use of wells were obtained. It is planned that the CGDP wells will be monitored under the proposed Project Extension. The monitoring will become an integral part of the newly created Planning Department of the WDA and the reporting of the results is expected to become institutionalized.

As a part of the Project Extension, the CGDP will cooperate with an FAO project to improve the water data system at the MMWR and to assist the National Water Technical Committee into a fully operating unit. Reporting on the monitoring of wells, it is planned, will then be made to the Technical Committee. Until recently, the data collection system at the MMWR and the Water Committee have not been functional to the degree required. Emphasis during the proposed CGDP Extension will be placed on assisting these organizations to become fully operational in order to meet the overall planning needs of water resource development in Somalia.

4. INSTITUTIONAL SUPPORT

4. INSTITUTIONAL SUPPORT

Institutional support to the WDA and MMWR has been provided throughout the life of the project. This support has been developed in response to particular needs and has been undertaken in the fields of training, financial and planning management, warehousing, vehicle maintenance, and water quality analysis.

4.1 Training

In order to assure continued utilization of techniques and methods utilized by LBI/RM staff in the development of groundwater resources, training of counterpart personnel has been emphasized. Training is a part of the institutional support supplied to WDA and MMWR staff in order to strengthen their overall capabilities. Training has been divided into components of on-the-job instruction, intensive seminars, university degree programs in the USA, short-term training in the USA, and English language instruction.

4.1.1 On-the-Job

On-the-job instruction has been provided by all LBI/RM staff to assigned counterpart personnel. This has consisted of continuous demonstration and periodic explanation of all project related activities. As such, on-the-job instruction has covered fields of endeavor that the CGDP has been involved in as part of its groundwater development activities. This includes, in the broadest sense, drill rig operation, pumping operations, hydrogeologic investigations, water distribution systems construction, water quality analysis, and socioeconomics analysis. In a more detailed sense, all of the aforementioned fields have been subdivided into many more elements which have been the subject of specific instructional matter. A list of these subjects is provided in Table 4.1, Outline for Classroom Training in Country Training Program - Somalia.

Counterpart personnel from the WDA and MMWR who have been assigned to the project include 150 staff members all of whom have received at least some on-the-job training. Most staff, particularly drillers, rig hands, pump crews, hydrogeologists, civil works engineers, chemists, loggers, and social monitors have received considerable on-the-job training over the three-year period of the project. Other project members, such as truck drivers and laborers, have received little training, although drivers have been given periodic lectures in driving safety and maintenance. This training has resulted in a cadre of counterpart personnel who are capable of undertaking the basic activities of a groundwater development program.

Table 4.1

OUTLINE FOR CLASSROOM TRAINING IN COUNTRY TRAINING PROGRAM - Somalia

Louis Berger - Roscoe Moss

I. BASIC GROUNDWATER GEOLOGY — Dr. Rainer Eckart

A. Map Reading

1. Scales
2. Grid Nets
3. Contour Intervals - Elevations-Surface Gradients
4. Symbols
5. Direction - Magnetic Declination
6. Triangulation
7. Drainage Patterns
8. Buried River Channels
9. Map Utilization - construct cross-sections, geology maps, depths to water surface and water table gradients, recharge areas, thickness of aquifer, structure contour maps, fence diagrams, and related features
10. Other Types of Maps - geologic, soils, engineering geology

B. Air Photos, Use and Interpretation — Phil Roark

1. Use as substitute for topographic maps
2. Scales
3. Stereoscopic pairs (overlap)
4. Photomosaics
5. Black and white, color
6. Side-looking radar

C. Remote Sensing

1. Satellite photos
2. Infrared photography

D. Groundwater Geology — Robert Turney & Roark

1. Hydrologic Cycle
2. Geologic Regimes in Groundwater Flow
   a. Alluvial
   b. Residual
   c. Sedimentary
   d. Crystalline
   e. Volcanic

Table 4.1 (Cont.)

3. Groundwater Balance - (Hydrologic Equation)
4. Groundwater Management
    a. Overdraft of Basin
    b. Monitoring of Water Levels
    c. Monitoring of Water Quality
    d. Meteorological Records
    e. Seawater Intrusion
    f. Artifical Recharges

II. APPLIED GEOPHYSICAL TECHNIQUES — Pehr Soderman

A. Geophysical Surveys

1. Seismic Surveys
2. Electrical Resistivity Surveys
3. Magnetometer Surveys
4. Gravimetric Surveys

B. Drill Hole Logs

1. Electrical logs - Equipment — Ross Bowman
2. Caliper logs
3. Temperature logs
4. Radiation logs

C. Evaluation of Borehole Logs

D. Photographic and Other Well Surveys

1. Single Vertical Photo Surveys
2. Stereo Photo Surveys
3. Television Surveys
4. Motion Picture Surveys
5. Other Well Surveys

III. COLLECTION OF CORRELATIVE DATA — Robert Turney or Dr. Faillace

A. Meteorological

1. Rainfall
2. Humidity
3. Evaporation
4. Evapotranspiration
5. Temperature

B. Well and Spring Records

1. Extractions
2. Water Levels
3. Water Quality
4. Flows
5. Wars
6. Underground Storage Quantities
7. Infiltration Rates
8. Surface Flows

Table 4.1 (Cont.)

C. Water Quality

1. Bacteriological
2. Chemical
3. Physical

D. Socioeconomic — Dr. Paul. Donnelly Roark

1. Discussion of social and technical information at field levels
2. Village meetings - purpose and use of data

IV. CONSTRUCTION OF WELLS — Jake Woerner

A. Methods of Drilling and Types of Equipment for Each

1. Cable Tool (Percussion)
2. Reverse Circulation
3. Mud Rotary
4. Air
5. Combination

B. Uses of Ingersoll Rand (TH-60) — Bruce Pike

1. Rig Capacities
2. Drilling Capabilities in Various Formation Using Air/Foam and Mud

C. Operation of Ingersoll Rand (TH-60)

1. Set-Up Rig
2. Drilling with Hammer
3. Drilling with Cone Bit
4. Reaming and Running Hole Openers
5. Operation and Air Compressor
6. Operation of Mud Pumps

D. Well Completion

1. Casing Installation
2. Gravel Packing
3. Cementing
4. Development

E. Well Sanitation and Prevention of Contamination

1. Sanitary Seals
2. Surface Sealings
3. Preventing Communication of Aquifers

F. Well Problems

1. Fishing
   a. Drilling Tools
   b. Casing
   c. Pumping

Table 4.1 (Cont.)

G. Rig Maintenance — Roy Steele

H. Safety Equipment

1. Accident Prevention
2. First Aid Procedures

I. Construction Inspection — Dr. Rainer Eckart

1. Check Casing Lengths and Types, Thicknesses
2. Check Screens for Openings, Length and Thicknesses
3. Check Drilling Depths, Penetration Rates
4. Identify Cuttings, Prepare Lithologic Logs
5. Measure Water Levels and Flows (Pump discharge)
   a. Orifice Plates
   b. Weir Box
   c. Open-Pipe Discharge
   d. Flow Meters

J. Well Development — Pehr Soderman

1. Objective: Remove Fines from Well Bore and Aquifer in the Vicinity of the Well
2. High Rate Pumping (Overpumping and Backwashing)
3. Use of Explosives in Crystalline Rocks
4. Surging (Intermittent Pumping, Surge Plungers)
5. High Velocity Jetting and Compressed Air
6. Chemical Agents
7. Pressure Acidizing - Acids in Clay Formations
8. Hydraulic Fracturing ("Hydrofracking")
9. Development Time
10. Post-Development Test

V. WELL AND AQUIFER DATA ANALYSIS — Dr. Rainer Eckart

A. Aquifer Characteristics - Definitions

B. Pump Test for Production

1. Fundamentals and Preparation
2. Step-Drawdown - Four Rates
3. Continuous Test at Selected Rate
4. Recovery Test

C. Analysis of Test Results

1. Aquifer Characteristics
2. a. Specific Capacity
   b. Transmissivity
   c. Storage Coefficient

Table 4.1 (Cont.)

D. Pump Motor Selection Criteria — Bud Kellums

1. Total Dynamic Head
2. Horsepower
3. Type of Pump
4. Depth Setting

VI. PUMPS — Bud Kellums

A. Submersible Pumps

1. Fundamentals
   a. Advantages
   b. Disadvantages
2. Pump Repair
   a. Fundamentals
   b. Trouble Shooting
   c. Preventative Maintenance
3. Pump Controls
4. Generators

B. Line Shaft Pumps

1. Pump Applications
   a. Fundamentals
   b. Advantages
   c. Disadvantages
   d. Performance Curve Evaluation
2. Pump repair
3. Drive Unit
   a. Fundamentals
   b. Advantages
   c. Disadvantages
   d. Operation
   e. Preventative Maintenance: Short-term vs. Long-term

C. Hand Pumps

1. Pump Applications
   a. Fundamentals
   b. Advantages
   c. Disadvantages
   d. Performance Curve Evaluation
2. Pump Repair

D. Jack Pump

1. Pump Applications
   a. Fundamentals
   b. Advantages
   c. Disadvantages
   d. Performance Evaluation
2. Pump Repair

3. Drive Unit
   a. Fundamentals
   b. Advantages
   c. Disadvantages
   d. Operation
   e. Preventative Maintenance
   f. Repair

E. <u>Windmill</u>

1. Fundamentals
2. Operation

F. Solar Power

G. Pump Rig Safety

VI. <u>K A R S T</u> Robert Turney

A. <u>Nature of Karst</u>

1. Meaning of Karst
2. Types of Karst
3. Pseudokarst
4. Karst Literature and Terminology
5. Methods of Investigation

B. <u>Karst Rocks</u>

1. Limestone
2. Reef Facies
3. Dolomite
4. Evaporites
5. Pores and Planes of Weakness: Permeability and Strength

C. <u>Karst Processes</u>

1. Solution and Precipitation
2. Piping
3. Subsidence
4. Collapse
5. Other Weathering Processes

D. <u>Minor Solution Sculpture</u>

1. Factors Affecting Minor Solution Sculpture
2. Types of Minor Solution Form on Limestone and Other Rocks

E. <u>Drainage</u>

1. Infiltration, Overland Flow, and Throughflow
2. Surface Rivers: Regimes; Sinking of Rivers

Table 4.1 (Cont.)

3. Springs: Regimes
4. Relation of Surface and Underground Drainage
5. Theory of Karst Hydrology

F. Surface Landforms

1. Gorges
2. Meander Caves
3. Natural Bridges
4. Construction Action of Rivers
5. Semiblind Valleys
6. Blind Valleys
7. Steepheads
8. Dry Valley
9. Dolines and Cockpits
10. Uvalas
11. Poljes
12. Karst Margin Plains

G. Karst Caves

1. General Characteristics
2. Cave Formation
3. Morphometric Analysis of Caves
4. Underground Solution

H. Influence of Climate and Rates of Denudation

1. Rates of Karst Denudation
2. Arid vs Cold Extremes
3. Tropical Humid Karst
4. Karst Climato-Morphogenic Systems

I. Influence of Geological Structure

1. Depositional Relief in Reef and Dune Limestone Karsts
2. Structural Relief in Reef Karst
3. Holokarst and Merokarst
4. Structure in Tropical Humid Karsts
5. Structure within Caves
6. Hydrogeologic Systems

J. Historical Geomorphology of Karst

1. The Karst Cycle
2. Climatic Change
3. Tectonic Movements and Changes of Base Levels
4. Complex Evolution

K. Present State of Karst Geomorphology and its Value

VII. WELL REHABILITATION — Robert Turney

A. Problems with Wells

1. Collapsed or Broken Casing or Screen

Table 4.1 (Cont.)

2. Pumping Sand
3. Water Quality Changes
4. Decrease in Discharge
   a. Incrustation
   b. Corrosion
5. Polluted

B. Perform an Adequate Investigation

1. History of Well and Physical Characteristics
   a. Original Pump Test Results
   b. Groundwater Hydrographs of Area
   c. Quality of Water

C. Causes of Well Problems

D. Rehabilitation Methods

1. Sand Pumping
2. Decline in Discharge
3. Shooting with Explosives and Acidizing
4. Chlorine Treatment
5. Rehabilitation of Rock Wells

VIII. WATER QUALITY Dr. Magnus Edgren

A. Statistic Tools

B. Alkalinity in Natural Waters

C. Relationship Between Weathering and Water Composition

Note: A manual for chemical methods is in preparation to be used at the laboratory. It will be in both Somali and English.

IX. MAINTENANCE

A. Safety

1. Prevention of Playful Actions Around the Rig
2. Suitable Clothing for the Job
3. Working While Sick - Inform Driller
4. Reporting Broken, Loose, Unusual Equipment
5. Attention to Cable Clamps

B. Cleanliness

1. Keeping Rig and Surrounding Areas Clean
2. Clean up Oil Spillage and Leaks
3. Report Leaks as You Find Them

Table 4.1 (Cont.)

a. Gear Boxes
b. Hydraulic Hoses
c. Others

C. <u>Maintenance</u>

1. Responsibility of Crew Members
2. Oil Levels: Instruction on Problems of Overfill
3. Use of Tools: Damage to parts
4. Being Observant and Using Common Sense

X. <u>ELECTRICITY</u> Ron Myers

A. <u>Theory of Electricity</u>

1. Proper Use and Care of Test Equipment and Tools
2. Basic Theory of Electricity

B. <u>Theory on How Motors Work</u>

1. Break down and Assembly of Electric Motors
2. Trouble Shooting Electric Motors
3. Repairing Electric Motors
4. How to Check for Proper Rotation of Motors

C. <u>Theory on Generators</u>

1. Breakdown and Asembly of Generators
2. Troubleshooting Generators
3. Repairing Generators

D. <u>Study of High and Low Voltages</u>

1. How it Affects a Motor
2. What Damage it Can Do to Motors
3. Proper Wire Sizes

E. <u>Study of Relays</u>

1. What They Are
2. What They Do
3. How They Work

F. <u>Study of Control Panels</u>

1. What They Do
2. How They Work
3. Troubleshooting and Repair

G. <u>Study of Capacitors</u>

1. What They Do

Table 4.1 (Cont.)

2. Why They are Used
3. How They Work

XI. TRAINING OUTLINE FOR ASSISTANT HYDROGEOLOGISTS — Dr. Rainer Eckart

A. Sample Taking

B. Water Levels

Use of Sounders

C. Water Quality

1. Use of EC Meters - Instructions
2. Instruction, Maintenance and Repair
3. Sample Bottles and Sampling

D. Rock Identification

1. Basic Minerals - Hardness, Acid
2. Sieving Tests - Diagrams
3. Soil Classification

E. Map Reading

1. Distances
2. Altitudes
3. Contours
4. Scales

F. Pumping Test

1. Development 48 hours
2. Surging - Intermittent
3. Production 72 hours
4. Step Drawdown
5. Pump at Single Rate
6. Recovery 24 hours
7. Measurements of Discharge and Water Levels

G. Basics of Electrical Logging

H. Well Drilling Movie

I. Forms

J. Construction Inspection

1. Check Casing Length and Types, Thicknesses
2. Check Screens for Openings, Lengths and Thicknesses
3. Check Drilling Depths, Penetration Rates
4. Identity Cuttings, Prepare Lithologic Logs

K. Scientific English and Conversions

4.1.2 Seminars

Intensive seminars or classroom type training has been provided during two major periods. This training was scheduled during the rainy seasons when project field activities were necessarily shut down. Later it was found that, by planning sites which were accessible during the rainy season, most project activities could be continued during the rainy season with relatively few delays.

The development of a course curriculum was based on LBI/RM staff appraisals of the learning needs of counterpart personnel. An initial outline of course titles and subtitles was prepared for 10 areas of study. These areas of study were subdivided into specific subjects, a complete list of which is given in Table 4.1.

Because of the work locations, equipment needed for demonstrations, and sufficient room to handle large groups for training films, four locations were selected for training. Assistant hydrogeologists training was conducted in Baidoa; hydrogeologists seminar training was conducted in a classroom in the WDA building; drilling crews of approximately 45 persons were shown training films and given lectures in the auditorium located in the maintenance yard of WDA; and counterpart training for the electrician and geophysical technician were held at their workshop at the LBI office. Laboratory chemists and technicians received their training at the MMWR laboratory.

Training methods included the use of training films, slides with recorded lectures, demonstrations of processes using various type of equipment, overhead projector, blackboard instruction, textbooks and operational and maintenance manuals. For the English language films a more effective method was used in which the sound was turned off during the film and a WDA drilling superintendent described the picture in the Somali language. The texts included groundwater and applied hydrogeology as well as geologic dictionaries, drilling manuals on the cable tool and rotary methods of drilling. Portions of the operations manual for the Ingersoll Rand drilling equipment were translated into the Somali language. A simplified tri-language dictionary was prepared in Somali, Italian and English to facilitate communication between expatriates and non-English-speaking crew members.

The training seminars were conducted during two periods, the fall of 1982 and the spring of 1983, lasting five weeks each. The former session included all project personnel while the latter was confined to hydrogeologists as they required a more theoretical type of instruction. As a culmination of the seminar training certificates were issued during a ceremony on July 23, 1983 for all staff who successfully completed the training. A list of the trainees is included in Table 4.2.

Table 4.2

LIST OF WDA STAFF RECEIVING LBI CERTIFICATES

1. Askar Ibrahim Hussein
2. Yussef Abdi Said
3. Abdirazak Mohamed Abdulle
4. Abdi Mohamed Hashi
5. Mohamed Aden Muuse
6. Mohamed Omar Addow
7. Hassan Mohamed Abdi
8. Hashi Farah Samater
9. Aideed Salaad Hassan
10. Ahmed Mohamed Hassan
11. Aden Ali Jama
12. Abdi Hassan Muuse
13. Abdi Jama Samater
14. Khalif Arab Mohamed
15. Abdi Abshir Ismail
16. Mohamed Ahmed Ibrahim
17. Mohamed Sulub Abdi
18. Osman Ali Koshin
19. Ali Mohamed Alasow
20. Hassan Hussein Omar
21. Ali Mohamed Ibrahim
22. Mohamed Ahmed Raage
23. Abdi Jama Barre
24. Askar Ibrahim Hussein
25. Farah Mohamud Elmi
26. Muuse Sagadi Abdulle
27. Noor Hussein Abdulle
28. Abdullahi Mohamed Jama
29. Aden Yussef Mumin
30. Mohamud Mohamed Mahamud
31. Deerow Adbulle Mohamed
32. Hassan Ali Mohamed
33. Ahmed Ali Hassan
34. Abdi Hassasn Aw-Muse
35. Farah Mohamud Huusef
36. Ahmed Hilowle Mohamed
37. Noor Hassan Farah
38. Abdi Barre Haile
39. Ilyas Mohamed Mohamud
40. Ahmed Nadif Agip
41. Hassan Ahmed Egal
42. Said Farah Duale
43. Abdi Ahmed Warsame
44. Hassan Mohamud Aw-Essa
45. Hassan Hussein Ibrahim
46. Omar Hai Mohamed Shurie
47. Abdillahi Ahmed Ibrahim

Table 4.2 (cont.)

LIST OF WDA STAFF RECEIVING INGERSOLL-RAND CERTIFICATES

1. Dahir Macalin Hassan
2. Ismail Ali Ibrahim
3. Mohamed Ibrahim Adan
4. Shire Tahlil Awaale
5. Muhuden Noor Mohamed
6. Ashur Amin Osman
7. Ahmed Hassan Haji
8. Abdi Monamed Ahmed Warsame
9. Hashi Farah Samater
10. Aideed Salaad Hassan
11. Ahmed Mohamed Hassan
12. Aden Ali Jama
13. Abdi Jama Samater
14. Khalif Arab Mohamed
15. Abdi Abshir Ismail
16. Mohamed Ahmed Ibrahim
17. Mohamed Sulub Abdi
18. Osman Ali Koshin
19. Ali Mohamed Alasow
20. Hassan Hussein Omar
21. Mohamed Ahmed Raage
22. Abdi Jama Barre
23. Askar Ibrahim Hussein
24. Farah Mohamud Elmi
25. Muse Sagadi Abdulle
26. Abdi Hassan Muuse
27. Mohamed Aden Muuse

The training seminars were coordinated by Senior Hydrogeologist Bob Turney with lectures provided by, in addition to Turney, the following staff members:

Ross Bowman, Geophysical Technical
Dr. Rainer Eckart, Hydrogeologist
Dr. Magnus Edgren, Water Quality Chemist
Bud Kellums, Pump Technician
Phil Roark, Team Leader
Dr. Paula D. Roark, Consultant Sociologist
Pehr Soderman, Hydrogeologist
Jake Woerner, Drilling Supervisor

Apart from the LBI/RM regular staff, lectures were also provided by other consultants including Bruce Pike, Ingersoll Rand representative from Nairobi; Constantine Failiace, hydrogeologist assigned to WDA from GTZ; and Ron Schwartz, anthropologist. Dr. Schwartz provided instruction to Bay Region project personnel in social data collection. Six staff members from the BRADP took part in the instruction who were later assigned to work with the Wyoming social analysis team for the Bay Region.

4.1.3 University Degree Programs

Four counterpart staff members were selected for masters degree programs in the USA. Three staff members from the WDA, two chemists and one hydrogeologist, and one hydrogeologist from the MMWR are presently attending classes at the University of Arizona. This university was selected because of its emphasis on water resource studies and because of its arid zone location.

The chemists began their studies in September, 1983, and the hydrogeologists began in January, 1984. It is expected that each student will require 2½ years to complete their degree training.

The participants are:

Omar Mohamed Abdi	Chemist
Abdulkadir Sheikh Ali	"
Abdi Barre Haile	Hydrogeologist
Hassan Mohamud Aw Issa	"

4.1.4 Short-Term Training in USA

Eight counterpart personnel were selected to attend a two-month training session conducted by the USGS in Colorado. This session was scheduled during June-July, 1984. The USGS program consisted of a comprehensive program of water resource studies covering surface water, groundwater, water quality, measurement and instrumentation, and management techniques. Valuable insights are expected by participants from field trips which will allow first hand observations of techniques and conditions in the western USA. Participants included the following:

Hamud Hassan Duale	Chemist
Ali Hassan Roble	"
Hassan Noor Koshin	"
Abdi Elmi Weheliye	"
Abdi Hassan Aw Muuse	Hydrogeologist
Mohamed Abucar Muuse	"
Mohamud Mohamed Mohamud	Geophysicist
Saleh Farah Mohamed	"

4.1.5 English Language Training

In order to help overcome critical limitations in undertaking training activities, English language instruction has been provided to many counterpart personnel. Considerable technical training has either been diluted because of the limited English capacity of a majority of WDA staff, or not been provided at all to staff with no English background. Two organizations were utilized in providing this training.

First, the organization "Experiment in International Living" was contracted to provide four months of instruction. This was conducted from January 15 to May 15, 1983. Classes were taught on two levels, beginning and intermediate. For the intermediate speakers a TOEFL exam was utilized to select students for university training. Four students passed the exam although more scholarships would have been awarded if additional students had passed the exam.

Second, the USIS began English language instruction in the fall of 1983 and courses were set up for selected WDA staff. Twelve students, primarily hydrogeologists, took the lessons in order to raise their English capabilities to the level required for short-term training in the USA. Five months of twice a week instruction was provided and eventually eight staff members were selected for the training.

4.2 Finances and Management

As a part of institutional support to the WDA, advice has been provided both in finance management and in planning management.

Finance management has consisted of preparation of commodity specifications, budget submissions, and local purchases. Over $7 million in commodity purchases have been specified to provide the required equipment, tools, spare parts and vehicles. The actual procurement was contracted to specialized US procurement agents in most cases but liaison for receiving the commodities was undertaken by the project. Bob Van Valer of RM was primarily responsible for providing the commodity specifications.

Assistance was provided by the team leader, Phil Roark, in annual budget preparations for the CIPL unit. This required writing justifications and explanations of all required shilling expenditures for the project by the Somali government on a semi-annual basis. Line items included fuel, staff allowances, per diem, and local purchases. Monthly review of expenditures and semi-annual reporting of progress was required.

Specifications for local purchases of miscellaneous commodities in support of drilling operations was provided. In addition, monitoring of fuel supplies and assisting in the logistics of moving fuel to the required locations was given. Much of the latter was provided at Baidoa to support the Regional Director of the WDA.

Formal training in management was provided to the WDA Project Manager, Yussef Mohamed Elmi. Mr. Elmi completed a four week course given by the American Management Association in New York. This intensive course covered all aspects of business management and was given in September, 1983.

Planning management has been an integral part of project activities and will be a focus of future support during the Project Extension. A Planning Department does not exist within the WDA but plans have been formulated to begin a formal arrangement for institutionalizing a planning capability. Annual work plans were required as a normal part of Project activities and were prepared by Phil Roark in consultation with Yusset Mohamed Elmi, Deputy Director of WDA. This required extensive coordination meetings with BRADP and NRA staff as well as meetings with local officials primarily in the Bay Region.

It is significant to note that several factors have negatively influenced planning management beyond what could normally be expected. First, long delays in receiving needed project commodities did not allow the timely execution or coordination of project activities. Second, fuel supplies were constantly being disrupted which either slowed or sometimes stopped project activities. Finally, security precautions at times where imposed on planning designs. For future project endeavors, planning exercises must take into account the above indicated factors, although it is recognized as being exceedingly difficult, as these are problems which are largely beyond the scope of the project to control.

In addition to the problems cited above, another significant factor frequently hinders WDA management as well as other governmental organizations. WDA staff complain of low salaries, per diem, and other compensation. At times, WDA staff have refused or delayed work assignments because of their dissatisfaction with available compensation. During the course of the project, allowances and per diem have been raised but this has not kept pace with inflation and staff morale remains low. Some staff look for other means of supplementing their income which distracts from their WDA job assignments. Solutions to this problem are largely outside the scope of WDA management and will require a complete review by the Somali Civil Service Commission.

4.3 Warehousing

In order to systematically control the use of commodities purchased under the project, assistance in warehousing has been provided. Several discrete tasks are involved including importation, inspection of received merchandise, cataloging of merchandise, and inventory control. This process is complex and has been beset with difficulties during much of the project.

The importation of commodities has required extensive liaison with various commodity procurement companies in the USA. Communication involving changes in specifications, dates of delivery, and tracking of shipping both via air and sea has been constant and often difficult. Delays in procurement were numerous with the average time of procurement exceeding one year.

After the arrival of specified commodities in Mogadishu, interaction with port authorities also proved difficult. Shipping documents were not always complete, theft and damage of stored commodities occurred and arranging cranes and transportation was time consuming. In one instance the Somali military removed from the port a shipment of project commodities including 12 trucks and 3 containers, although it was later returned.

A system of cataloging and inventory control was established. This system required the systematic cataloging of all received commodities. This task was also made difficult by the frequent omission by the shipping agents of packing lists. Warehouse consultant Bob Cooper of RM established a card system for inventory control during two separate consultancy periods. LBI staff members Dennis Wick and Joe Sharp, General Service experts, have advised in the operation of the system.

While a system of inventory control has been established since the fall of 1981, the functioning of the system has been compromised by several changes in WDA employees. Each of the four warehousemen trained by Mr. Cooper has left the project for various reasons. This has required that warehouse staff replacements begin their work without an adequate background. Because of the abruptness of the departures, many records were left in incomplete or altered states. However, during the past six months, the warehouse has been functioning acceptably with the arrival of a stable group of WDA staff.

4.4 Vehicle Maintenance

At the beginning of the CGDP vehicle maintenance was undertaken by an interagency garage set up under an Agricultural Extension Project. All CGDP project vehicles were to have been serviced by the garage but, over time, the service became increasingly unacceptable, partially because of greater vehicle demands being placed on the garage by the various projects. It was therefore decided that the WDA should establish its own garage.

In May of 1983, a contract was established with a local firm to construct a garage and warehouse. Largely because of delays in funding of the contract, the garage was not completed until January, 1984. In July, 1983, LBI mechanic John Quackenbush arrived to begin vehicle maintenance operations. Without a garage, maintenance was done in the open air which was most difficult due to the harsh elements of heat, dust, and rain. Since January, however, the garage has been established with full maintenance capabilities including tools and spare parts. A schedule of preventive maintenance, repair, and training of counterparts is presently proceeding normally.

Heavy equipment maintenance, including drilling rigs and trucks has been established and has proceeded normally since the beginning of the Project under the direction of RM mechanic, Roy Steele.

4.5 Water Quality Analysis

The major institutional support provided to the MMWR has been to the water quality lab located at the Ministry. The LBI chemist, Magnus Edgren, has provided advice and training to the lab. As a result, the lab routinely undertakes water quality analysis for all CGDP samples and also for samples provided by other Somali and international organizations.

Analysis consists of providing values of physical parameters including Ca, Mg, Na, K, Cl, HCO_3, SO4, PH, EC, TDS, and on special request NO_2, F, Fe, SiO2, and NH4. Biological assessments of fecal coliform and fecal streptococus are also provided in the field with mobile kits.

Training in water quality analysis techniques and procedures has proceeded with MMWR and WDA chemists and with laboratory assistants. Presently, two chemists are undertaking graduate degrees in the USA and will be expected to assume management of the water quality lab upon their return.

An extensive list of commodities, including instruments and chemicals, have been provided to the lab. In addition, repairs of laboratory electronic equipment has been undertaken periodically by Ross Bowman, logging technician.

5. SOCIOLOGY

5. SOCIOLOGY

Sociological studies for the CGDP were undertaken primarily during the first year of activities. The results were reported in the "Exploratory Report for the Bay Region", and the reader is referred to this report for details. This work was completed by Paula Donnelly Roark, consultant for LBI. As a result of these studies, a methodology was developed and refined to assist in site selection by assessing village commitment to and need for a deep bore well. This methodology has been utilized, with some modifications, throughout the life of the project, and is considered important to achieving project success. The objectives of the sociological studies, a description of the process used, the results of the studies, and plans for the future requirements of sociology within the project are provided in the following sections.

5.1 Objectives of Sociological Studies

A primary objective of the CGDP is to strengthen the government's capability to install, operate, and maintain rural water supply systems. However, while the capabilities of installation and operation are technical in nature, the capability for maintenance of water technology is part of a broader development question, namely what social change is required in order for a society to adopt technology transferred from one culture to another culture. Water development experience in a variety of countries has illustrated that adequate long-term maintenance of wells is vulnerable to social and behavioral factors emanating from the accepting culture. The consensus is that though the technical phase may be successful in implementing the appropriate infrastructure, this alone has not been sufficient to assure its long-term viability. Typically, if the is not community motivation to maintain and support the improved water point, once the technology falls into disrepair, it is not fixed. The participant population returns to its traditional preproject modes of water procurement, and the water supply project, despite its initial successful technical implementation phase, will ultimately be classified as a failure.

The recognition that changes in technical delivery systems, no matter how beneficial to the participant population, requires corresponding changes in the socioeconomic support system at the local level and the institutional support system at the regional level, and has served to focus interest on the need for integration of technical and social factors in project implementation. There is increasing consensus that only through this sociotechnical integration can specific rural water supply projects encourage and engender the community participation and institutional cooperation needed to ensure adequate local support for long-term use and successful maintenance of the new water supplies at the community level.

Presently, at the organization level, project staff of international aid organizations are aware of the importance of this "sociotechnical integration," but as the World Bank suggests, "they are without an operational framework for integrating social and behavioral factors with engineering, economic, and institutional issues, and with the project cycle itself." Thus, one of the key strategies for the CGDP is the establishment and maintenance of organization and management techniques at both the project and institutional levels that will encourage and facilitate such sociotechnical integration.

The first requirement for any successful sociotechnical integration is that of adequate information. Therefore, just as the technical section of the CGDP has emphasized the gathering of information that will assure high levels of technical success in the production drilling for the Bay Region, the socioeconomic study, during the Exploratory Phase, has gathered information and defined processes that encourages and assists in, at both the local and national level, the sociotechnical integration of information and process that is needed for the long-term successful maintenance of the improved water points in the Bay Region.

5.2 Description of TVAPP

The project sociologist has identified and described the information needs and subsequent development of a research methodology for the CGDP. Three categories of information were defined as necessary to fulfill the sociological objectives for the Exploratory Phase of the project. They included: information for participation procedures; information for development of socioeconomic criteria for the placement of production wells; and information for the development of project monitoring and evaluation criteria. A specific and innovative methodology that would achieve both the data gathering and participatory objectives was dictated by these information and process needs. A theoretical framework based upon general systems theory and hypotheses concerning change at the local level, integrated with identified field conditions, was therefore developed and described. The resulting defined components formed the basis for the "Tuulo Village Assessment and Participation Process" (TVAPP).

The socioeconomic study of the Exploratory Phase has gathered information and defined process that encourages and assists in, at both the local and national level, the sociotechnical integration of information and process that is needed for the long-term successful maintenance of the improved water points in the Bay Region.

To meet the information and process needs described earlier the TVAPP was designed and field tested in the spring of 1982. The basic design incorporated the focus, strategy, and process of the general research methodology into a specific pattern of three serial visits to each of the Tuulo areas that had been selected for exploratory drilling activities.

The overall purpose of these meetings was to discuss with the community if they wished to become involved with the project, and, if so, what their participation responsibilities would consist of. The specific participation responsibilities of the Tuulo area, if they decided to become part of the CGDP, were the following:

1. Community assessment for information
2. Community work support of the actual installation of the borehole.
3. Community payment for the distribution system and construction of the partial payment of reoccurring costs.
4. Community management of the new water point for preventive maintenance and healthful use of water.

The first of the three meetings had the primary objective of information exchange. The project collected information concerning the quantity, quality, reliability, access, and traditional management of existing water supplies. In exchange, the community leaders were provided with information concerning the CGDP and the Tuulo responsibilities if they decided to participate. A significant amount of time was spent in the information exchange concerning the negative as well as the positive effects of improved water supply. The participants of the first meeting were usually confined to Tuulo elders.

The second TVAPP meeting was styled as a Tuulo area meeting for all the people designated in the designated area. Specifically, it was requested that representatives from all the Tuulos or satellite villages be in attendance. The objectives were twofold. First, the project was again explained to everyone in attendance to assure a complete understanding and it was asked if there were any changes to be recommended. Second, an explanation of the community assessment was provided, specifically providing instructions on how to complete the questionnaire. The purpose of the questionnaire was to assist in the siting of the well within the Tuulo area and to provide some baseline data so as to later measure the impact of the well on the population. After the meeting, a request was often made to assist the hydrogeologists in finding sinkholes in the vicinity. In the limestone areas of the Bay Region this was utilized as an indication of sites of potential groundwater.

The third meeting required the participation of the Tuulo Committee, the Water Committee and the representatives from the Tuulos who worked on the questionnaire. The objective of the meeting was to review the questionnaire to make sure the information was complete and to choose the actual site for drilling. If, from a hydrogeologic point of view, several sites looked equally promising, the community was given a choice as to the site. If one particular site was decided more favorable from a hydrogeologic view point, then the community was asked to approve that site. Finally, instructions were given for community work in constructing a trail and clearing the proposed well site, if necessary, and the date that drilling was scheduled to begin.

In most cases, the TVAPP, as described in the preceding paragraphs, was carried out completely wherever wells were proposed within "villages". Meetings did not take place, of course, for those sites that were outside of "villages". This included wells for road construction or in areas designated for range development. Most wells in the Bay Region required the TVAPP process but none in the Central Rangelands. The Central Rangelands well sites had, however, been studied as part of the range management plans developed by the CRP. In several instances, the TVAPP process was not undertaken completely because of lack of personnel, fuel shortages, or other reasons. While the lack of a TVAPP was regrettable, it did not appear to have a negative effect in the Bay Region since most of the Tuulos knew, from the projects reputation which was learned from other villages, what the respsonsibilities and conditions of acceptance were for having a well project in their village.

The most important feature of the TVAPP was to assure a complete understanding of the expectations and responsibilities of the community. It was always clearly emphasized that there was no guarantee of finding water. If water was encountered during drilling and pump testing and the well was deemed suitable as a production well then a fourth meeting was held to arrange for the construction of the storage and distribution systems. Again, an exchange of information between the project and the community was the key objective in order to assure the best possible solution to meeting the communities needs. Work requirements were specified and a plan developed for construction activities. The arrangements for civil works construction was undertaken by David Boggs and Mohamed Burale Guled.

5.3 Socio Study Results

Baseline data has been collected in four areas of emphasis: organization of local communities; local water management systems; community production systems; and community demographics. Information concerning organization of communities and production systems of communities was partially gathered during the TVAPP program, but was also supplemented with group and individual interviews. Especially helpful were the "women's meetings" which, as a gathering of the principal water purveyors, often provided important insights into water-related questions. The details of this baseline data are fully described in the "Exploratory Report for the Bay Region".

The water use of the Bay Region displayed patterns which were generally typical of underdeveloped rural areas. Distance to the water source was the dominant factor in per capita water consumption. Since most water is traditionally supplied from wars, there is a large difference, between the rainy season when all wars are filled and the dry season when few wars retain water, in per capita consumption. Dry season consumption was found to be only about 3 liters per person per day (pdpp) for people requiring a long distance to walk to the water source. For people within 500 meters of the well, consumption was 12 liters pdpp during the dry season. These consumption rates must be considered as life sustaining only and any lower rates of consumption, because of disruption in the existing water supply, would be disastrous.

Women are the typical carriers of water. For short distances of a few kilometers, the water is carried by women in clay pot containers. If very long distances are involved, then donkeys or camels are used to carry the water. Dry season distances to water sources vary considerably but it is not unusual to find water being transported 10 kilometers and more. Under these conditions, procuring water is clearly a full-time job during the dry season for many women.

Water quality has been measured and reported in other sections of this report. However, it is important to emphasize that there are large differences in acceptance of the amount of salinity by water users in the Bay Region. Many people, particularly in the southern part of the Bay Region, receive water from hand dug wells or springs which are often extremely salty. They have necessarily developed an acceptance of water which is well beyond the recommended limits of salinity. Bacteriological contamination of open water sources is, of course, present everywhere. Improved water quality from project wells will therefore not necessarily be recognized by the local people as their standards differ from scientific standards. A program of water hygiene education will be necessary to fully maximize the benefits available from improved water sources. Such a program is potentially available through the on-going Primary Health Care Project.

5.4 Recommended Criteria for Site Selection

Provision of adequate water supply is basic to the realization of Somalia's stated development goal to reduce rural poverty. However, because adequate universal water provision is an unreachable goal for the near future, the question of who will receive the initial water systems in specific areas, after they have been technically defined as feasible for groundwater exploitation, becomes most important. The identification and explanation of criteria to guide this decisionmaking process is necessary for adequate long-term planning in the provision of rural water supply for people and livestock.

The identification of socioeconomic criteria for the siting of the CGDP/WDA water wells was a major objective of the baseline study. The baseline study has identified three primary criteria and two secondary criteria that will: 1) positively assist the overall selection process; 2) is congruent with present national and regional institutional development objectives: 3) will enhance local support for maintenance; 4) will enhance equity at the local level; 5) and will increase rural participation.

These primary and secondary socioeconomic criteria for selection of well sites are listed below:

Primary

1. Distance. Population centers in which there is not a year-around water point within five kilometers.

2. Local Management of Resources. Population centers that have traditional water committees and are willing to include the new CGDP/WDA water point in their present schemes, or those population centers that are willing to form a water committee to carry out the needed local maintenance.

3. Population Centers serving over 1,000 people, or those which have a state school or primary health care unit.

Secondary

4. Identified arable areas that are utilized because of lack of minimal water resources.

5. Identified transhumant areas where a new water source would improve nomadic movements.

5.5 Future Use of the TVAPP

As was indicated previously, the TVAPP was not implemented fully in some well locations because of the lack of qualified staff from either LBI/RM or WDA. In order to alleviate the problem, two solutions were attempted. First, an anthropological consultant, Ron Schwarz, was brought to Somalia to train BRADP staff in the use of the TVAPP. This approach was recommended by the USAID evaluation team which evaluated the project in March, 1983. Dr. Schwarz proposed to expand the TVAPP and trained BRADP "monitors" in the use of the methodology. However, only very limited use of the trained personnel was affected as the monitors were assigned full-time to the sociological study program being conducted for BRADP by the University of Wyoming.

Arrangements were also proposed with a newly formed monitoring and evaluation unit within the Ministry of Plan to provide monitoring of social impacts from the water project. This also did not proceed to expectations because of different priorities established by the unit. The Monitoring Unit is, however, monitoring some selected sites in the Bay Region, which include wells developed by the CGDP, and which may provide some useful insights in time.

In the future, under the proposed 18 month project extension, emphasis will be placed on developing the Planning Department within the WDA. To assist the Planning Department a full time LBI sociologist will be assigned to the Department. In addition, 2 or 3 Somali sociologists are to be employed by the WDA as permanent members of the Department. With this staffing the CGDP will for the first time in the history of the project, be capable of fully carrying out the recommended sociological interventions. Emphasis will be placed during the Extension Period on monitoring the completed wells to assure that the wells satisfactorily meet the needs of the water users and to recommend modifications in operations if required.

The operation of the newly constructed water wells have provided an indication of the short-term success of CGDP technical activities. The long-term success of the CGDP, is however, in great measure dependent upon community support and motivation to maintain the new water point. Thus, adequate community participation activities are a recognized factor in the long-term success of the CGDP installed water points.

The socioeconomic activities undertaken within the Exploratory Phase of the CGDP offers to the project and WDA a substantive and innovative operational framework within which to achieve the needed community support and motivation. In addition, this operational framework, or the TVAPP, integrates sociological and technical project activities and information. A primary function of the TVAPP organizational framework is to integrate project inputs and outputs in a time frame that takes into account and puts into equilibrium the community participation process with the technical process. In a broader sense this is comparable to the equilibrium necessary for any integrated rural development strategy between the top down, or institutional inputs, and the bottom up, or community inputs.

6. ECONOMICS

6. ECONOMICS

An economic evaluation of the CGDP was completed in April, 1984. This evaluation was based on information collected over a two-year period and resulted in a report, to which the reader is referred for in-depth details, entitled, "Economic Evaluation of the Comprehensive Groundwater Development Project." The report was completed by LBI economist Carter Brandon.

The primary purpose of the study was to estimate the long-term cost to the Somali government of producing wells. As such, it encompases the hydrogeology of the project area, the site selection procedures, and the actual working conditions under which the CGDP was undertaken. A discussion of benefits was included in a general manner, but insufficient water user data did not allow the quantification of benefits.

The economic evaluation consisted of three distinct parts:

1. an analysis of the full costs of a Groundwater Development Program for a period of ten years.

2. an analysis of projected benefits, measured by the number of water points completed, the approximate number of beneficiaries, and the qualitative type of benefits to be expected.

3. an analysis of the long-term well operating and maintenance costs, with a review of possible financing of these costs through user fee collection.

A time frame, 1982-1991, was chosen as the projected life of the most long-lived and expensive capital equipment purchased under the CGDP, which was three rotary drill rigs. An annualized average cost per well was calculated based upon an assumed annual well completion rate.

The costing of the program took into account the following:

- capital equipment costs;

- all WDA salary, materials, equipment, fuel, and workshop costs;

- WDA administrative overhead;

- well operating and maintenance costs.

The costing analysis did not include:

- expatriate salary costs (the expatriate consultant staff under CGDP is serving primarily as advisors and trainers of WDA groundwater personnel, and their costs do not represent recurring costs to the Somali government;)

- expatriate housing and support costs;

- Somali training costs (the USAID program to send Somali technical personnel to the U.S. for university training is not a well production cost.)

6.1 Utilization of the Economic Report

It is expected that the results of the economic study will be used in several ways. First, it provides a financial guide to all future planning of the CGDP program. By explicitly determining direct, indirect, and capital costs, and by distinguishing between past or sunk costs and future cost projections, it is possible to estimate the annual financial needs of the project. Also, these estimates can be easily varied as more information on well-drilling rates, costs, and capital equipment life expectancy becomes available.

Second, it can be used by the Somali government as a basis for requesting future foreign assistance, if necessary. The study looks at the degree to which the project can be self-financing by estimating what percentage of total costs are recoverable through user fees. It also looks at the foreign exchange requirements of continuing the groundwater project.

Third, as more information becomes available on the alternatives to drilled wells in Somalia, such as surface reservoirs, this report will allow useful comparisons of costs of different technologies and development strategies. Similarly, as more information becomes available on project benefits, a more detailed cost-benefit analysis could be easily undertaken and used as a basis for comparing technologies and development priorities.

Fourth, the report can be used to compare the cost of constructing wells in Somalia with that of similar programs in other countries. In this way, it can be of use to policy and program offices of the various international donor agencies.

6.2 Well Production, Operation and Maintenance Costs

All costs associated with the CGDP have been divided into three categories: direct per well costs, indirect costs, and capital costs. A summary of all of these costs appears in Table 6.1. Direct costs are broken down by diesel and hand-pumped wells, and by construction and recurrent (operating and maintenance) costs. Overhead costs, including indirect costs (labor and materials) and capital costs, appear as a lump sum. Also shown

Table 6.1

COSTS OF WELL CONSTRUCTION AND MAINTENANCE, ASSUMING NORMAL EQUIPMENT LIFE AND HIGH PRODUCTION RATES
18 WELLS PER YEAR (in thousands of constant 1983 dollars)

	Net Present Value (i = 15%)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
I. Direct Costs														
A. Construction Costs														
- Diesel Wells														
Number of Wells	45	10	10	10	10	10	10	10	10					
Cost	2,401	535	535	535	535	535	535	535	535					
- Hand-pump Wells														
Number of Wells	36	8	8	8	8	8	8	8	8					
Cost	757	169	169	169	169	169	169	169	169					
- Exploratory and Failed Wells														
Number of Wells	54	12	12	12	12	12	12	12	12					
Cost	374	83	83	83	83	83	83	83	83					
— Subtotal	3,532	787	787	787	787	787	787	787	787					
B. Operating and Maintenance Costs														
- Diesel Wells														
Number of Wells	227	5	15	25	35	45	55	65	75	80	80	75	65	55
Cost	2,043	32	95	230	322	414	506	598	690	736	736	690	598	506
- Hand-pump Wells														
Number of Wells	182	4	12	20	28	36	44	52	60	64	64	60	52	46
Cost	38	1	2	9	13	16	20	23	27	29	29	27	23	21
— Subtotal	2,110	32	97	239	335	430	526	621	717	765	765	717	621	527
II. Overhead Costs														
- Indirect Costs (labor and Materials)	1,535	342	342	342	342	342	342	342	342					
- Sunk Capital Costs	6,066													
- Recurring Capital Costs	4,058	542	877	1,452	777	672	1,712	777	483					
— Subtotal	11,658	884	1,219	1,794	1,119	1,014	2,054	1,119	825					
III. Total Costs	17,301	1,704	2,103	2,820	2,241	2,231	3,367	2,528	2,329	765	765	717	621	527

IV. Average Costs

Average Construction Cost per well, including sunk capital costs = $188,000
Average Construction Cost per well, excluding sunk capital costs = $113,000

Average Total Cost per Year of well service, including sunk costs = $42,000
Average Total Cost per Year of well service, excluding sunk costs = $27,000

are the number of diesel and hand-pumped wells assumed to be constructed in each year, and the cumulative number of wells in service for each year.

The first column of Table 6.1 shows the net present value of each of the cost streams, discounted at the rate of 15%. For the purpose of calculating the per well costs, the number of wells constructed and the cumulative number of wells in service are discounted at the same rate. The discounting of the physical number of wells has the same significance as the discounting of costs: It reflects the increased value of a well in service now over one in service in the future. In order to calculate average costs per well, the cost net present values are divided through by the net present value of the number of wells constructed and operated.

Average costs per well are affected by many factors, of which the most important are (a) direct and indirect costs, (b) the annual project production rate, and (c) the service life of the capital equipment. Assumptions concerning these factors are varied in order to calculate an indicative range of average costs. Specifically, the assumptions made were:

1. the average well service life would be ten years;

2. normal expected equipment life would be ten years for the heavy drill and pipe rigs; shortened life would be seven years service; and extended life would be fifteen years service;

3. averge well costs should be calculated both with and without the $6.1 million 'sunk' capital costs;

4. a high annual production rate for the three rotary drill rigs would be 30 boreholes per year, of which 18 would become production wells (10 diesel and 8 hand-pumped);

5. a high failure rate would be only 12 production wells per year (7 diesel and 5 hand-pumped) for the thirty boreholes;

6. a low production rate would be 20 boreholes and 10 production wells per year (6 diesel and 4 hand-pumped).

For the set of 'normal' assumptions embedded in Table 6.1 (normal equipment life and high production rates), the average costs per well are shown at the bottom of the tables. The four average costs are: (1) average construction costs including sunk capital costs ($188,000), (2) average construction costs excluding sunk capital costs ($113,000), (3) average costs per year of well service, including all construction, capital and service costs ($42,000), and (4) average costs per year of well service, including all costs except sunk capital costs ($27,000). These costs show that sunk capital costs are a very large part of total costs: when sunk capital costs are excluded, total costs decrease by almost 40%. In order to bring down the overall cost per well, therefore, it is important to keep the equipment procured under CGDP-I operating as long as possible.

When the assumptions concerning production rates and projected equipment life are varied, a full range of average costs can be calculated. In Table 6.2, it is seen that:

1. average construction costs per well range from $188,000 to $307,000, and total cost per year of well service ranges from $42,000 to $66,000, depending on the assumptions. When sunk capital costs are excluded, these costs range from $113,000 to $172,000, and $27,500 to $39,600, respectively.

2. average construction costs rise by 50% between the high and low production rate assumptions, and by only 35-40% between the high production and high failure rate assumptions. It is, therefore, economically more sensible to produce as many wells as possible, even if the success rate drops, than to drill a small number of wells.

3. the sensitivity of costs to the production rate shows the costly impact of fuel shortages and other logistical problems. Accordingly, any steps that can be taken at a reasonable cost to minimize logistical difficulties are likely to have very high payoffs.

4. total costs per year of well service rise by 20% between the normal and shortened capital equipment life assumptions. It is important to keep the heavy equipment operating for at least ten years. After ten years, however, the average costs per well remain about constant: this is because the recurrent costs of capital upkeep offset the lower costs derived from prolonged equipment life.

5. average construction costs per diesel well are about $32,000 (or 15% more than for hand-pumped wells), and average costs per year of well service are about $15,000 (or 30% more). In those locations where a diesel pump is required (i.e. where there are both sufficient water resources and sufficient demand) the higher costs would be offset by the benefits of serving a larger number of beneficiaries.

In order to analyze costs further, the three cost categories--direct, indirect, and capital costs--have been broken down

Table 6.2

SUMMARY OF WELL CONSTRUCTION AND OPERATING COSTS
(in constant 1983 dollars)

Assumption/ Type of Well	Average Construction per Well: High Production Rate	Average Construction per Well: High Failure Rate	Average Construction per Well: Low Production Rate	Total Cost per Year of Well Service: High Production Rate	Total Cost per Year of Well Service: High Failure Rate	Total Cost per Year of Well Service: Low Production Rate
I. Including All Capital Costs						
A. Normal Equipment Life						
Diesel Pumps	202,500	280,400	320,200	49,000	63,700	72,300
Hand-pumps	170,100	248,000	287,900	33,800	48,800	57,300
Average Cost	188,100	266,900	307,300	42,300	57,400	66,300
B. Shortened Equipment Life						
Diesel Pumps	226,100	314,800	361,600	56,900	74,600	85,700
Hand-pumps	193,700	282,400	329,200	41,600	59,300	70,300
Average Cost	211,700	301,300	348,600	50,100	68,200	79,500
C. Extended Equipment Life						
Diesel pumps	191,200	263,600	300,100	50,500	65,300	74,200
Hand-pumps	158,800	231,200	267,700	34,900	49,800	58,500
Average Cost	176,800	250,100	287,100	43,600	58,800	67,900
II. Excluding Sunk Capital Costs						
A. Normal Equipment Life						
Diesel Pumps	127,400	167,800	185,100	34,200	41,700	45,600
Hand-pumps	95,000	135,400	152,700	19,000	26,800	30,600
Average Cost	113,000	154,300	172,100	27,500	35,500	39,600
B. Shortened Equipment Life						
Diesel Pumps	125,600	164,000	180,600	35,600	43,200	47,300
Hand-pumps	93,200	131,600	148,200	20,200	27,900	31,900
Average Cost	111,200	150,500	167,600	28,700	36,800	41,100
C. Extended Equipment Life						
Diesel Pumps	129,100	170,300	188,100	37,000	45,400	49,900
Hand-pumps	96,700	137,900	155,700	21,400	29,900	34,200
Average Cost	114,700	156,800	175,200	30,100	38,900	43,600

along the lines of project activities. This allowed the estimate of costs associated with each phase of work. The six types of activities were:

1. site selection
2. well drilling, logging, and development
3. well testing
4. final installation
5. well operation and maintenance
6. central office, warehouse, and workshop

Table 6-3 shows the same cost accounting matrix, but now complete with the values calculated in the last three sections. With this matrix, not only can total costs per well and/or per year be calculated, a complete breakdown of costs between direct, indirect, and capital costs, and by type of activity, can be readily seen. The figures in Table 6.3 show the full cost of producing and operating wells for the middle case (high failure rate) shown in Table 6.2. This table shows that:

1. the direct cost of well installation, operating and maintenance is about 27% of the total;

2. the indirect cost is about 11% of the total;

3. the annualized capital cost of the project, including sunk capital costs, is about 62% of the total. The annualized capital costs are calculated using the appropriate capital recovery factor.

When the total cost is divided up along the lines of the six project activities, the percentage breakdown is:

	Direct and Indirect Cost	Total Costs
1. site selection	1.1%	7.5%
2. well drilling and logging	23.7%	45.5%
3. well testing	1.3%	3.2%
4. final installations	22.0%	16.5%
5. operation and maintenance	23.7%	11.1%
6. central office overhead	28.2%	16.2%

The up-front costs of well planning, drilling, and construction represent about 89% of the total cost of each well. The operation, maintenance, and monitoring costs, which are calculated as a ten-year obligation, are only about 11% of the total cost. Although well maintenance represents a small part of the budget, effective maintenance is essential to the success of the project.

Table 6.3

ESTIMATED ANNUAL COST OF THE GROUNDWATER DEVELOPMENT PROJECT FOR THE YEARS 1984-1991, US$
(# -- See Assumptions Below)

	Direct Costs					Indirect Costs						Capital Costs						Total Costs	
	Labor	Materials	Fuel	Subtotal	% of Total	Labor	Materials	Fuel	Misc. Overhead	Subtotal	% of Total	Heavy Rigs	Heavy Vehicles	Light Vehicles	Light Equipment	Subtotal	% of Total	Total	% of Total
1. Site Selection (inc. hydrological, geophysical, and socioeconomic evaluation)	2,292	--	11,604	13,896	1.60	22,336	--	8,705	--	31,041	9.07	--	--	103,031	94,364	197,395	9.79	242,332	7.50
2. Well Drilling (inc. well drilling, setting of casing and screen, and logging)	27,990	175,608	83,286	286,884	32.96	47,655	--	19,231	--	66,886	19.54	547,000	438,353	103,031	27,368	1,115,753	55.32	1,469,523	45.50
3. Well Testing (inc. pump and water quality testing)	912	2,880	12,504	16,296	1.87	11,096	--	3,482	--	14,577	4.26	--	--	44,156	29,649	73,805	3.66	104,679	3.24
4. Final Installation (inc. civil works and pump installation)	3,051	241,884	21,237	266,172	30.58	30,021	--	7,459	--	37,499	10.96	26,500	109,588	88,313	5,702	230,102	11.41	533,774	16.53
5. Well Operation, Maintenance and Monitoring for 10 Years	181,871	31,570	73,670	287,111	32.99	--	--	--	--	--	--	26,500	--	44,156	--	70,656	3.50	357,767	11.08
6. Central Office (inc. admin., GSO, workshop, warehouse)	--	--	--	--	--	84,394	55,811	30,014	22,037	192,256	56.17	--	73,059	88,313	167,917	329,288	16.33	521,544	16.15
Total of column	216,116	451,942	202,301	870,359	100.00	195,501	55,811	68,910	22,037	342,259	100.00	600,000	621,000	471,600	325,000	2,017,000	100.00	3,229,618	100.00
Percent of Total Cost (%)	6.69	13.99	6.26	26.95	--	6.05	1.73	2.13	.68	10.60	--	18.58	19.23	14.58	10.06	62.45	--	100.00	--
Average Cost per Well	18,010	37,662	16,858	72,530	--	16,292	4,651	5,743	1,136	28,522	--	50,000	51,750	39,250	27,083	168,083	--	269,135	--

Note: (#) Assuming 12 production wells per year (7 diesel and 5 handpumps), normal capital equipment life, and i=15%.

A graphic summary of these basic findings appears in Figure 6.1. The second graph shows the high (62%) component of capital costs. The graph underscores a previous conclusion; namely, that if the capital procurements under the CGDP are considered as sunk costs, which they effectively are, then the continuation of the Comprehensive Groundwater Project is very cost effective. The marginal, or future cost of continuing the project would be much lower than the historic cost.

6.3 Summary of Well Costs

The full cost of drilling wells has been calculated and summarized in Table 6.2. The cost of construction of an averge well, including "sunk" capital costs (defined as the $6.1 million of capital equipment procured under CGDP-I), is about $200,000-$280,000, and the average cost of providing one year of well service, including all costs, is about $45,000-$60,000. When "sunk" capital costs are excluded, these costs decrease to only $120,000-$160,000, and $200,000-$35,000, respectively. These costs are for what is defined as an average well--whose assumed average depth, diameter, type of pump, and period of use, are all based on the past experience of CGDP.

Of the total cost of an average well, more than 60% is the capital cost of the heavy equipment and tools used by the project, and less than 40% is the cost of the materials, labor, fuel, and overhead required by each well. The finding that capital costs are such a large part of total costs is important in several respects:

1. The marginal cost of constructing each additional well, once the capital equipment has been procured, is a small part of the total.

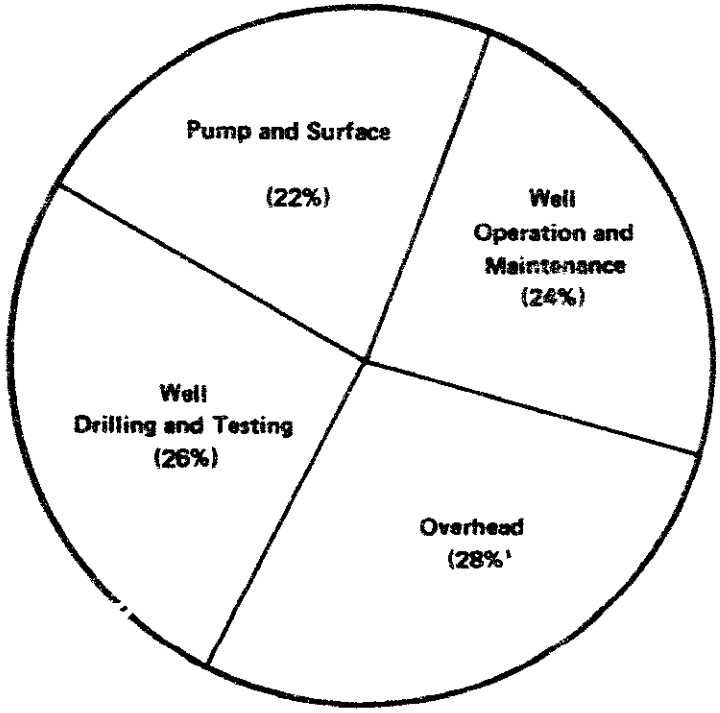
2. Any attempt to cut costs should focus first and foremost on the procurement of capital equipment. Any given reduction in capital costs, say 10%, would lead to much greater cost savings than an equivalent reduction in direct costs or overhead. It was not the purpose of the economic analysis to judge where, if at all, capital expenditures have been excessive; rather this report enables project planners and evaluators to see the high incidence of capital costs, to weigh the impact of specific changes or savings, and to compare the procurements of this project with that of other well-drilling programs.

3. The program costs are very sensitive to the expected life of the capital equipment, since longer equipment life means that the capital equipment costs can be spread out over a greater number of years and over a greater number of wells. If the drill rigs are only used for seven, as opposed to ten years, the average cost per year of well service would rise by 20%.

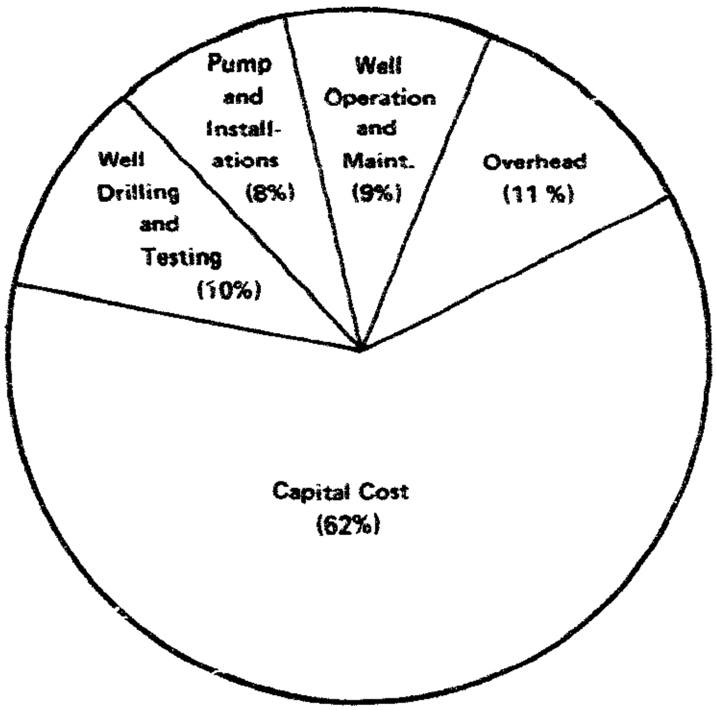
FIGURE 6.1

CONSTRUCTION AND OPERATION COSTS , PER WELL (*)

A. Direct and Indirect Costs Only



B. Direct, Indirect, and Capital Costs



(*) ASSUMING i = 15%, NORMAL EQUIPMENT LIFE, AND WELL OPERATION FOR 10 YEARS

4. <u>Maintaining a high annual well production rate is essential</u> to keeping per well costs at an acceptable level. This is because annual fixed costs, including both capital costs and overhead, together account for 70% of program costs. A 44% reduction on the assumed well completion rate, from 18 to 10 wells per year, would increase total costs per year of well service by almost 60%. A higher drilling rate reduces average costs, even if the rate of well failure increases.

5. Since the cost of capital equipment is such a large part of program costs, the <u>original choice of technology is an extremely important determinant of costs.</u> The costs for the CGDP have been estimated for a period of ten years, which is the projected lifespan of the three rotary drill rigs. The CGDP is, essentially, locked in to the use of the rotary drill rig technology. Planners of future similar groundwater projects should be able to compare the costs shown here with those of other technological alternatives in order to choose the most appropriate technology for achieving the desired results at the lowest overall cost.

6.4 <u>Benefits</u>

The data used in the evaluation of project benefits was less detailed than for costs and the results were much more tentative. An effort was not made to quantify benefits, but rather to estimate the number and type of project beneficiaries, and to describe the type and relative importance of the water-related benefits.

In both project areas, water demand will be quite seasonal, due to (a) the availability of surface water in the wet seasons which allows a much shorter carrying distance for many people and (b) the fact that traditional surface water sources are free of charge. In the dry season, however, the wells will enable significant improvements in water availability and water quality. By averaging projected demand throughout the year, estimates were made of the annual average number of people and animals using wells in the Bay Region and Central Rangelands, and of the required pumping times.

In the Bay Region, it is estimated that the average annual number of beneficiaries per well would be about 1,500 to 2,500 people, together with an equal number of family livestock (measured as livestock units). This is equivalent to an average user population, per well, of about 300-400 families and their household livestock.

The provision of clean year-round water in the Bay Region will generate important public health benefits in the form of reduced incidence of water-related diseases. It will also free up significant labor resources, especially of women, currently devoted to drawing water. Other project-generated benefits will be (a) agricultural production benefits gained by sedentarizing populations that currently migrate away from their home villages during the dry seasons, (b) livestock production benefits attributable to increased water availability and improvements in water quality and (c) the potential for improved range management and grazing patterns that would lead to more productive grazing areas.

In the Central Rangelands, it is more difficult to estimate the number of future project beneficiaries because of the paucity of data on the population, livestock, and water requirements of the specific areas (called degans) under consideration. However, it can be assumed that during the harsh dry seasons, one well will serve the residents of from one to three degans, and that most wells will operate at or near to capacity. Dry season demand is likely to be the equivalent of about 250 families and their associated livestock, up to a total of 7,000 livestock units. Wet season demand will probably drop off to almost nothing, as in the Bay Region. Any estimates of an annual average number of beneficiaries would be conjecture, but would fall somewhere between these two extremes.

6.5 User Fees

The current government water tariff, which is 10 SS per m^3, is sufficient at the projected levels of demand to pay the government back for all of its operating and maintenance costs, and slightly more than half of its direct costs incurred in constructing diesel wells. The direct costs are those costs such as labor, fuel, and materials (pumps, well casing, cement, etc.) that are used in the construction of each well. A tariff of 20 SS/m^3 could generate enough revenue to recover both project direct and indirect costs. Even this higher tariff would not, however, generate enough revenues to even approach those required to recover the capital cost of the project.

It has been recommended that the government explore the possibility of collecting periodic lump-sum payments from well users, as opposed to unit payments. It is possible that lump sum payments would (a) increase the volume of water consumed, especially during the wet seasons, with a corresponding increase in health benefits, (b) increase total revenues, (c) simplify the administration of the revenue-collecting body, and (d) correspond more closely with the traditional manner with which villagers organize and administer water resource, thereby improving village participation and sense of responsibility.

The determination of user fees should be based on concerns of equity. The question of how much should a rural inhabitant have to pay for water can only be answered by the concerned Somali authorities. Raising the fees to cover a higher percentage of costs will, at some point, result in reduced water consumption which is, obviously, an undesirable outcome. Rural water supply must be evaluated along with urban water supply in determining an equitable distribution of costs as the question of whether urban dwellers should share in those costs is appropriate.

It has been the conclusion of the economic analysis that, if 18 production wells per year are constructed, if the project's capital equipment is well-maintained, and if sufficient attention is paid to the collection of water fees, then the CGDP can become partially self-supporting. The direct costs and overhead could become almost entirely user-financed, and only the capital costs would require either government subsidy or foreign assistance.

6.6 Economic Analysis Conclusions

In conclusion, the future of the CGDP will probably reply upon two kinds of foreign assistance:

1. Assistance in the procurement of capital equipment

   To date, about $6 million has been spent on the procurement of capital equipment, and it is projected that $7.3 million more will be required between 1985 and 1991 to keep the program operating at current levels. It is not foreseen that this cost, all of which would be a foreign exchange cost to the Somali government, will be recoverable through well user fees. Unless the Somali government appears willing to devote general revenues to the procurement of well-drilling capital equipment, foreign aid will be required to keep the groundwater project going. The projected capital needs are modest, however, slightly more than $1 million per year through 1991.

2. Technical assistance

   In order to maintain that target rate of 18 production wells per year and to keep equipment operating, continued technical assistance will be necessary. This assistance includes, in particular, hydrogeologists to assure a high percentage of production wells, mechanics to keep equipment operational, and planning and logistics experts to assure coordination of activities.

The economic analysis has calculated the basic costs of the project's well-drilling activities, taken initial steps towards estimating project benefits, and establishing financial targets for the user-financing of well construction costs. It is expected that these results will assist the government of Somalia and interested donor agencies in planning the future of groundwater development.

7. ENVIRONMENTAL ASSESSMENT

7. ENVIRONMENTAL ASSESSMENT

In order to assess potential environmental impacts resulting from groundwater development, an assessment of project activities was undertaken and a report was subsequently written by LBI consultant Mark Pape in May, 1982, entitled, "Preliminary Analysis of the Potential Environmental Impacts of the CGDP". The assessment considered the following subjects - impacts of well construction, aquifer mixing and contamination, physical impacts of well operation, and social impacts of well operation.

7.1 Well Construction

During construction, the impacts of damage to rural roads, disposal of materials from the well, and aquifer contamination from the introduction of foreign materials have been considered. The presence of heavy trucks going to and from a well site on unimproved roads may cause minor and localized damage. Usually, however, village labor is required for road construction and such tracks can be easily repaired.

Cuttings, soil, and rock which are removed from a well are routinely scattered in the near vicinity of the well. Drilling fluids such as bentonite clay and drilling foam are mixed with the cuttings but these materials are inert and non-toxic and pose no environmental or health problems.

Some of the drilling fluids are lost in the subsurface rock strata in the near vicinity of the well. The amount of losses is dependent upon the drilling conditions. Well development normally removes most of these materials. Because of the chemical nature of the drilling fluid, the introduction of such fluids into the aquifer does not appear to pose a significant environmental problem.

Casing, screen, gravel packs, pumps, and cement are other materials that are permanently placed in a well. The project uses both steel and PVC as casing and screen. All of these materials are manufactured for the purpose of use in water wells and do not pose a significant threat to the aquifer or its users.

7.2 Aquifer Contamination

Potential aquifer contamination, which arises at the time of construction and continues throughout the life of the well, is a concern. Chemical contamination is not seen as problem but biological contamination from surface or near surface water could potentially occur. The biological contamination results from animal or human wastes in the near vicinity of the well which infiltrate into the well itself. Proper well construction and maintenance techniques are necessary to minimize the risk of biologic contamination. Similarly, proper filling and closing of wells after their retirement will minimize the risks of aquifer contamination by abandoned wells. Training has been provided in the recommended techniques used for sealing a completed well; however, the actual procedures are site dependent and vary with actual conditions.

7.3 Well Operation

The physical impacts on the environment of well operation include the depletion of a regional aquifer, land subsidence, defoliation and surface erosion resulting from the use of a well. Land subsidence is considered to be insignificant.

A hydrologic review of the safe yield (pumping rate which will not permanently lower an aquifer) was undertaken. Calculations were made showing the areal concentration of wells and the withdrawal rates necessary to deplete an aquifer under the rainfall and recharge conditions found in the Bay and Central Rangelands. Although recharge rates are relatively low, particularly in the low rainfall areas of the Central Rangelands, proposed pumping rates and densities of wells are well below the level whereby aquifer depletion is likely to occur.

Surface erosion is considered a potentially significant problem. It may occur when, because of a large increase in concentration of animals, overgrazing defoliates vegetation, leaving the soil exposed. Erosion and possibly desertification may then occur from water or wind effects. To mitigate the potential erosion hazards, a range management plan needs to be in place before the well is constructed. The need for a management plan, before the well is constructed, has been emphasized to the NRA and BRADP who are the Somali Agencies responsible for developing range plans in the project area.

7.4 Social Impacts

Primary and secondary social impacts resulting from well operation include improved health, productivity, and quality of life to the users. These primary impacts are all seen as beneficial, though difficult to measure. Water borne diseases are probably the most prevalent diseases in Somalia and result in significant loss of human production. Improved water quality and quantity can be expected to provide a significant improvement in health benefits. This is especially true for people who live within the near vicinity of the well. Others, who live further from the well, can be expected to use less water which will result in less benefits.

The potential secondary impacts of increased production (human and livestock) in the vicinity of a well and the resultant increase in stress on the area's resources are potential concerns during normal years. However, the impact during abnormally bad years, when prolonged drought, crop failure or pump failure occur, can be a major problem. It is statistically certain that such events will occur and contingency plans need to be in place to help alleviate the problems. A well-conceived monitoring program will provide baseline data and early indicators of human and livestock problems around a well and of environmental stress that may result.

Table 7.1 provides a listing of the "Potential Environmental Impacts of Wells". In summary, the major potential impacts of well construction that must be of concern to the environment are those of defoliation, surface erosion, and unsupportable population growth around wells. No other potential impacts appear to create significant regional risks.

Table 7.1: Potential Environmental Impacts of CGDP Wells

Impact Considered	Water-Well Staff	Significant Risks Regional	Significant Risks Local	Recommended Actions
Damage to Access Tracks	Construction	No	No	adequately addressed no
Removal and Disposal of Material from well	Construction	No	No	adequately addressed now
Aquifer Contamination by Insertion of Material in well	Construction	No	No	adequately addressed now
Aquifer Contamination by Water Source Mixing	Construction	No	No	---
	Operation	Minor	Possible	o proper construction techniques o proper consturction materials o proper operation and maintenance
	Retirement	Possible	Possible	o filling and sealing at closure
Aquifer Depletion	Operation	No	Possible	o dependent on site-specific characteristics
Land Subsidence	Operation	No	Possible	o dependent on site-specific characteristics
Defoliation and Surface Erosion around well	Operation	Minor	Yea	o research, planning, management o monitoring of grazing zones for all livestock wells o monitoring of foliage and use of all wells o coordination of efforts with other Government of Somalia agencies

Table 7.1: Potential Environmental Impacts of CGDP Wells (Continued)

Impact Considered	Water-Well Staff	Significant Risks		Recommended Actions
		Regional	Local	
Villager's Health Villager's Productivity Villager's Quality of life	Operation	No	Improvements expected	o no action necessary o monitoring for research purpose
Population Increases beyond Long-term carrying capacity	Operation	Minor	Yes	o research, planning and monitori of carrying capacity and popula around well o coordination of efforts with other Government of Somalia Agencies

8. RECOMMENDATIONS AND CONCLUSIONS

8. RECOMMENDATION AND CONCLUSIONS

The CGDP has completed three years of work during which time significant progress has been made in all areas of activity. Because of the long time required to procure and ship commodities to Somalia, the CGDP has only been fully operational, with required equipment and materials, since early 1984. During that time progress has been significantly enhanced. Many previously drilled wells have become operational by installing pumps, drilling has continued in both the Bay Region and Central Rangelands, and data collection and training has also been continued. However, in order for the WDA and MMWR to achieve a status of high operational efficiency in the installation, operation, and maintenance of rural water systems, much remains to be done. The following brief comments are to serve as points of reference from which, it is proposed, the WDA and MMWR will continue to progress in the future.

1. Within the Bay Region, the Limestone Plateau contains moderate quantities of groundwater in the Baidoa formation. Wells in this zone are deep, averaging about 120 meters.

2. Quantities of water in the Limestone Plateau will be sufficient for village and stockwater needs only. A few of the wells could possibly support irrigation for small plots, but this would be unusual.

3. Other areas of the Bay Region are underlain by a Basement Complex and further drilling is not likely to produce wells of sufficient quantity or quality.

4. Water quality is a limiting factor in certain areas of Somalia. High salinity values are found primarily with chlorides and sulfates as the major constituents.

5. Drilling in the Central Rangelands has been difficult geologically, logistically, and from the point of view of security. These problems, plus the vastness of the areas, allow only preliminary observations. Groundwater development, at this time, can only be analyzed on a site-by-site basis.

6. Significant improvement by many WDA and MMWR staff in technical capabilities has been observed. More intense training is required for hydrogeologists and mechanics in particular.

7. Greater progress would be possible for counterpart staff if they were satisfied with their salaries and per diem. Significant time is lost in discussing job requirements in relation to remuneration. It is noted

that this is not uniquely a problem of the WDA but exists elsewhere within government organizations. This point underlines a proposed USAID study of the civil service system.

8. Logistics and planning are considered weak points within the WDA and emphasis will be placed on strengthening the proposed Planning Department within the WDA during the Project Extension.

9. The Planning Department is expected to develop a monitoring and evaluation capability which is important to assure long-term success of the wells. Continued use of the TVAPP or modifications thereof is recommended.

10. A functioning Operation and Maintenance Unit should be emphasized during the Extension Phase again to assure long-term operational capabilities of the wells.

11. The continued assistance of the two LBI/RM mechanics is vitally important to assure the mechanical condition of equipment and to continue training of counterpart staff. The newly created garage at the WDA has been successful in maintaining the existing vehicles and keeping down time to a minimum.

9. BIBLIOGRAPHY

9. BIBLIOGRAPHY

Abrens, T.B., Azzaroli, A. "A Reconnaissance Groundwater Survey of Somalia, East Africa." Rome, 1951.

Abdullahi A. Ahmend and Paula Donnelly Roark. "Community Participation and Successful Long-Term Maintenance on Rural Water Supply in Upper Volta and Somalia." Comprehensive Groundwater Development Project. 1982.

Altichieri, L., Angelucci, A., Boccaletti, M., Cabdukadir, M.M. "Preliminary Study on the Paleogene Formation of Central Somalia (Hiran, Galgaduud, Mudug and Nugal Regional." Lineamenti Geologici della Somalia, Volume 6. Mogadishu, 1983.

Angelucci, A., Barbieri, F., Maxamed, C.M., Caruush, M.C., Piccole, G. "Preliminary report on the Jurassic sequence in the Gedo and Bay regions (south western Somalia)" Lineamenti Geologici della Somalia Quaderni di Geologia della Somalia Volume V & VI. Mogadishu, 1982.

Azzaroli, A. "L'oligocene e il Miocene della Somalia, Stratigrafia, Tettonica, Palaeontologica." Pisa, 1958.

Barness, S.U. "Geology and Oil Prospects of Somalia, East Africa." American Association of Petroleum Geogosits Bulletin, Vol. 60, Nr. 3. March, 1976.

BelTrandi, M.D. and A. Pyre. "Geological Evaluation of Southwest Somalia."

Bibliography of Selected References on Waters of Somalia. October, 1979.

Daniels, J.L., Sciba, W.J., Sutton, J. "The Deformation of Some Branded Gabbros in the Northern Somalia Fold Belt." Geol. Soc. London Quart. Jour. Vol. 121, m. III - 12. 1965.

Dijon, Robert E. "Groundwater in Somalia Republic." April, 1967.

ELF. "Annual Progress Report on Petroleum Exploration Operation in 1970." Mogadiscio, Somalia, 1971.

Faillace, C. "Surface and Groundwater Resources of the Scebeli Valley, Mogadiscio." November, 1964.

Feachem, R. "Water Supplies for Low-Income Communities, Resource Allocation, Planning and design for a Crisis Situation." Water, Wastes, and Health in Hot Climates. Wiley and Sons, London, 1977.

Food and Agricultural Organization. "Reports on Agriculture and Water Surveys." (Vols. I - VIII), Vol, II, Water Resources. 1958.

Food and Agricultural Organization. "Draft Report to the Bay Regional Agricultural Development Project." Preparation Mission. Vol. II (Annex 5 to 13). Rome, 1977.

Food and Agricultural Organization. "Surface Water Resources." Report to the Government of Somalia. Rome, 1973.

Food and Agricultural Organization. "Water Use in Irrigated Agriculture, Democratic Republic of Somalia, A Country Brief." Rome, 1977.

Food and Agricultural Organization. Water Resources Report. FAO/SF:36 Som Vol. III.

GTZ. "Burco, Technical Report Extension of Well Field - Well Drilling-Hydrogeology." Report to Water Development Agency. 1981.

German Planning and Economic Advisory Group. "A Program for the Allocation of Deep Wells to Rural Areas." 1976.

Goulet, Denis. "The Uncertain Promise: Value Conflicts in Technology Transfer." I Doc, New York. 1977.

Hammer Petroleum Co. Final Report (C Domenico) a) Geology of the Baidoa Oddur area (Western Somalia)." October, 1966, Mogadiscio. b) "Geology of the Southern Flank of the Bur Uplift (El Wak-Mandera Basin, Western Somalia)." Mogadiscio, January, 1967,

Hilal, A.F., Pavan, G., Robba, E. "Geologia stratigrafica della Somalia." Lineamenti Geologici della Somalia Quaderni di Geologia della Somalia, Volume 6. Mogadishu, 1982.

Hunt, J.A. "Geology of Somaliland Protectorate." 1944-1950.

Hunting Technical Services, Ltd. "Bay Region Agricultural Development Project." Ministry of Agriculture, Somali Democratic Republic. 1982.

Indreland, J.B. "Failure and Aging of Water Well Casing and Compressive Rupture, Encrustation, and Corrosion." Roscoe Moss Company, 1978.

Indrotecneco. "Hydrogeologic Study of the Bur Region." 1975.

Indrotecneco. "Hydrogeological Study in the Bur Region." Phase I. Reconnaissance and Experimental Surveys. Final Report. December, 1976.

Imboden, Nicolas. "Planning and Design of Rural Drinking Water Projects." Occassional Paper # 2. OECD Development Center, Paris, 1977.

IRC. "Participation and Education in Community Water Supply and Sanitation Programs: a Literature Review." Prepared by Chritisne Van Wijk - Sijbesma. WHO International Reference Center for Community Water Supply. 1979.

Jennings, J.N. "Karst." The M.I.T. Press, Cambridge, Mass.

Johnson, James H., Consultant Hydrogeologist. "A Conceptual Review of Somalia's Groundwater Resources."

Johnson, James H. "Groundwater Resources of the Bay Region." Working Paper No. 1. Somalia Bay Region Agricultural Development Project. For the World Bank Preliminary Plan. June, 1977.

Loehnert, E.P. "Geochemical Interpretation and Evaluation of Groundwater in Southwestern Somalia," (Upper and Lower Giuba Region).

Louis Berger, International, Inc. "Inception Report" for the Democratic Republic of Somalia, Ministry of Mineral and Water Resources, Water Development Agency. August, 1981.

Louis Berger, International, Inc. "Exploratory Drilling Program for the Bay Region." January, 1982.

MacFadyen, P.A. "Water Supply and Geology of Parts of British Somaliland." 1951.

Mikhailov, B.M. "Weathering in the Arid Tropics of East Africa." 1971.

Mineralia Somali. "Final Report." Mogadiscio, 1963.

Ministry of National Planning, Statistical Abstracts.

Mobil Petroleum Co. "Final Report on Geological Study of the Hiran Province in the Somalia Basin." Mogadiscio, Somalia, 1964.

Moss, Roscoe. "A Guide to Water Well Casing and Screen Selection."

National Council of Research - Italy. "Geological Map of Ethiopia and Somalia." (Scale 1: 2,000,000). 1973.

Pape, Mark. "Preliminary Economic Analysis Comprehensive Groundwater Development Project." Louis Berger International Inc., May, 1982.

Pape, Mark. "Potential Environmental Impacts of the Comprehensive Groundwater Development Project." Louis Berger International Inc., May, 1982.

Putman, Diana B. "Preliminary Socio-Economic Survey of Bay Region, Somalia." Sept., 1982.

Ralph A. Parsons Corp. "A Final Report, Production Well Construction Phase III, Mogadiscio Water Supply." Los Angeles and New York.

Resource Management & Research. "Somali Democratic Republic, Central Rangelands Survey." Volume I, Part 3.

Roark, Paula Donnelly. "Phase I Socioeconomic Report." CGDP. Louis Berger International, Inc., March, 1982.

Roark, Paula Donnelly. "Women in Water." Socioeconomic Perspectives of Rural Water Supply. Academic Press, NY. 1983.

Saunders, Robert J. "Economic Benefits of Potable Water Supplies in Rural Areas of Developing Countries." American Water Works Association. 1975.

Sinclair Somal Corporation. "Subsurface Geological Map of Central and Southern Somalia Showing Structure on Top of Middle Jurassic." Plate 5, 68, Mog.

Soc. Cartografica G. De Agostini - Milan. "Topographic Map." Scale 1:400,000.

Somali Oil Ex. "Sedimentary Deposits of the Protectorate of British Somaliland."

Standard Methods for the Examination of Water and Waste Water, 15th Edition. 1980.

Standard Vacuum Oil Co. "Geology of the Somali Basin, 60-61."

Train, E.T. "Quality Criteria for Water." US Environmental Protection Agency, Castle House Publications LTD.

United Nations Children's Fund, "Technical Report Refugee Water Supply Project, Somali Democratic Republic." Mogadiscio, August, 1982.

UNDP. "Mineral and Groundwater Survey of Somalia." Mogadiscio, April, 1968.

UNDP. "Mineral and Groundwater Survey," Interim Report. New York, 1970.

UNDP. Mineral and Groundwater Survey (Phase II & Phase III) Somalia. "Groundwater in the Somali Democratic Republic," Technical Report 3. New York, 1973.

United Nations Special Fund. "Geologic Map of the Bur Area Somalia." Scale 1: 200,000. Mineral and Groundwater Survey. 1969.

United Republic of Tanzania, Ministry of Water Development and Power. "Maji Review," Vol. I. 1974.

USAID. "Somalia Comprehensive Project," Project Paper 649-0104, Washington, D.C. 20523. September, 1979.

U.S. Department of the Interior, Bureau of Reclamation. "Drainage Manual," A Water Resource Technical Publication, United States Government Printing Office. Washington, 1978.

Ven Te Chow. "Handbook of Applied Hydrology, Compendium of Water-Resource Technology." McGraw-Hill Book Company, 1964.

White, Gilbert F., Bradley, Daird J. and White, Anne U. "Drawers of Water: Domestic Water Use in East Africa." University of Chicago Press, London, 1972.

Wilson, George. "Groundwater Geology in Somalia." Mogadiscio, Somalia, June, 1958.

World Health Organization, "European Standards for Drinking Water." Geneva, 1970.

World Health Organization, "International Standards for Drinking Water." International Water Supply Congress, Zurich, Switzerland, 6-10 September, 1982.