No. 4

BASIC DESIGN STUDY REPORT
ON
THE URBAN WATER SUPPLY PROJECT
IN
THE SOCIALIST REPUBLIC OF THE UNION OF BURMA

MARCH 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Socialist Republic of the Union of Burma, the Government of Japan decided to conduct a Basic Design Study for the Urban Water Supply Project and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Burma a study team headed by Dr. Yasumoto Magara from September 11th to November 18th 1984.

The team had discussions with the officials concerned of the Government of the Socialist Republic of the Union of Burma and conducted a field survey in the Sagaing, Mandalay, Magwe areas in Burma. After the team returned to Japan futher studies were made and the present report has been prepared.

I hope that this report will serve for the develoment of the Project and contribute to the promotion of friendly relations between our two countries.

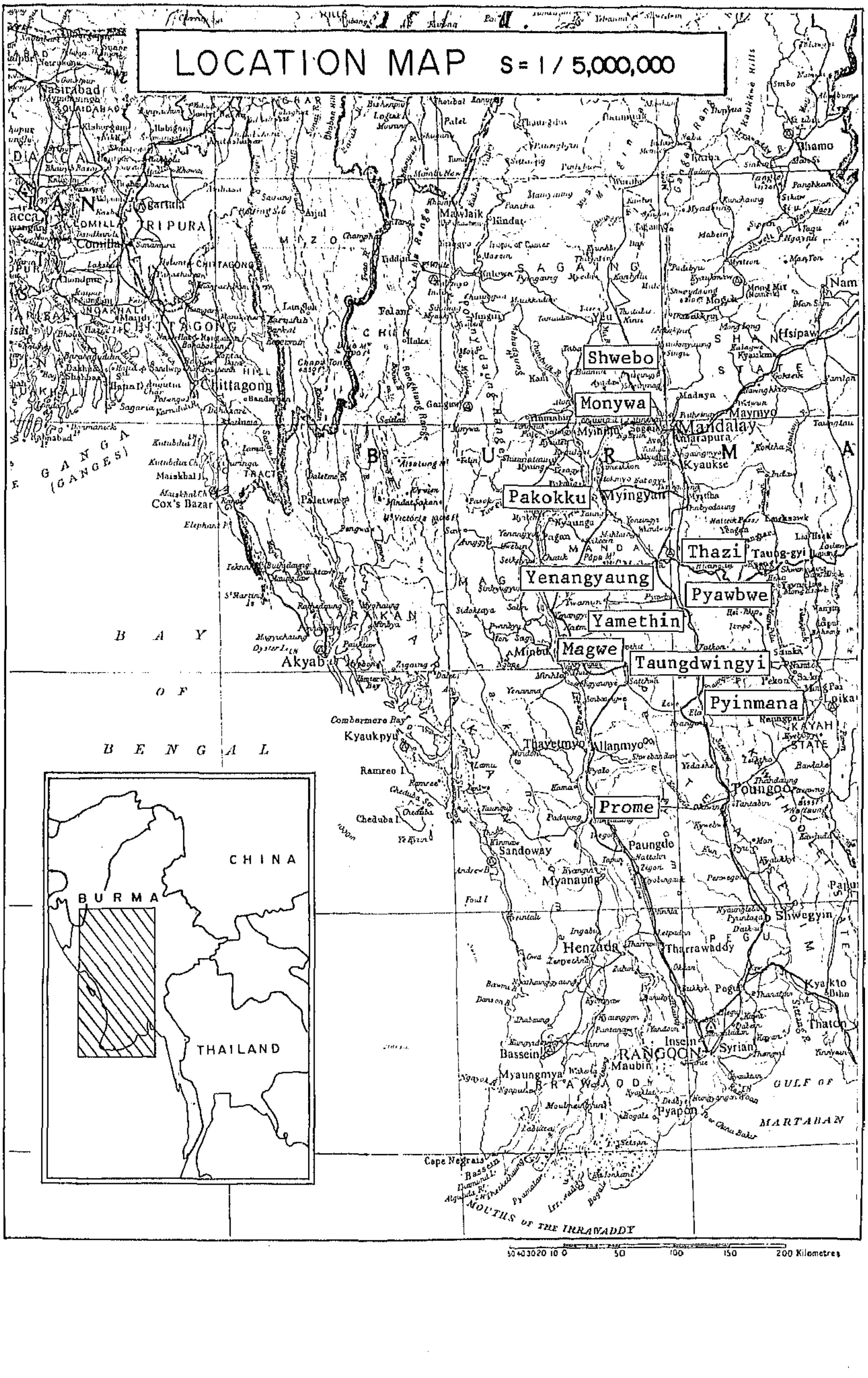
I wish to express my deep appreciation to the officials concerned of the Government of the Socialist Republic of the Union of Burma for the close cooperation extended to the team.

March, 1985

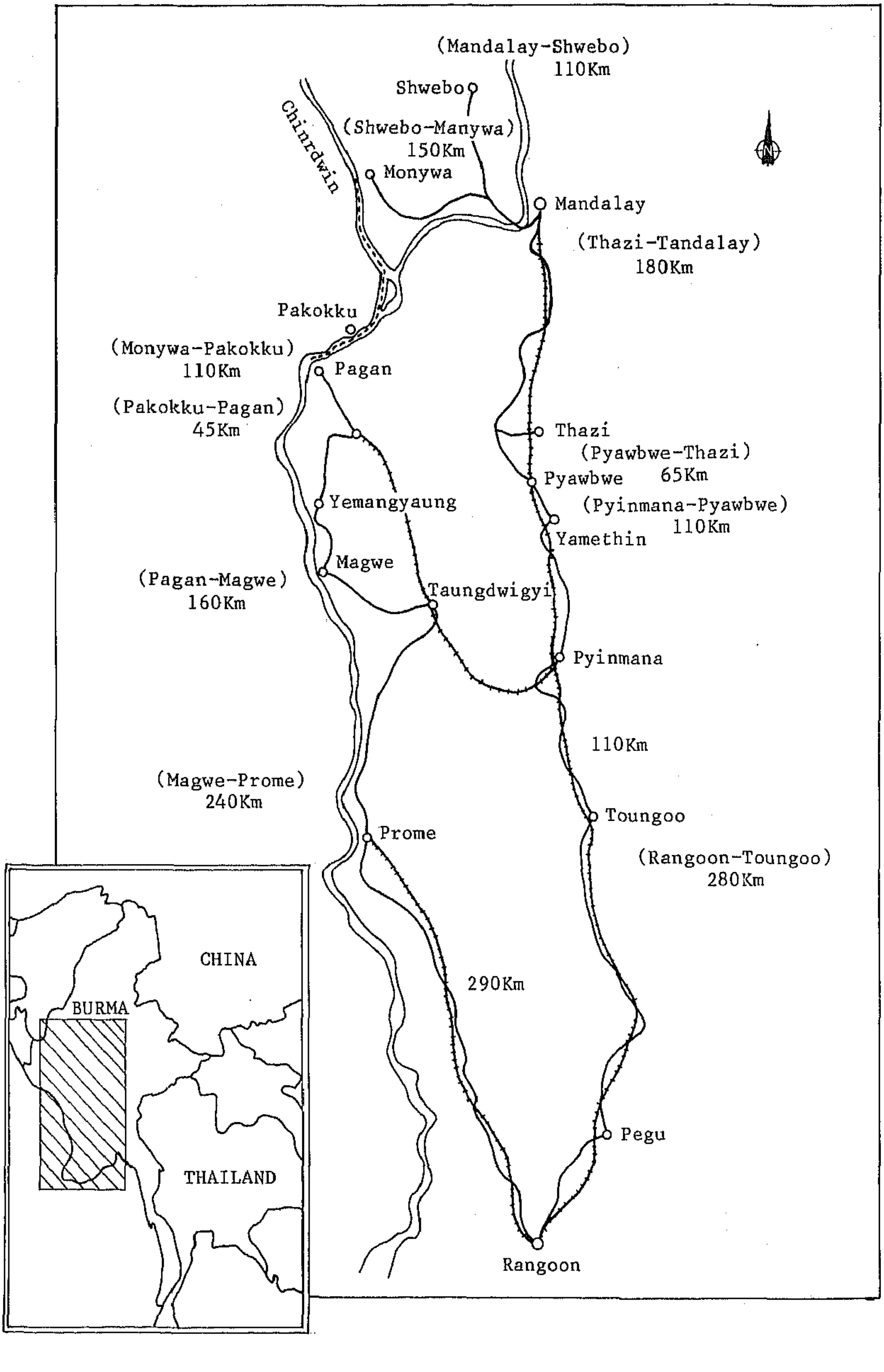
Keisuke Arita

President

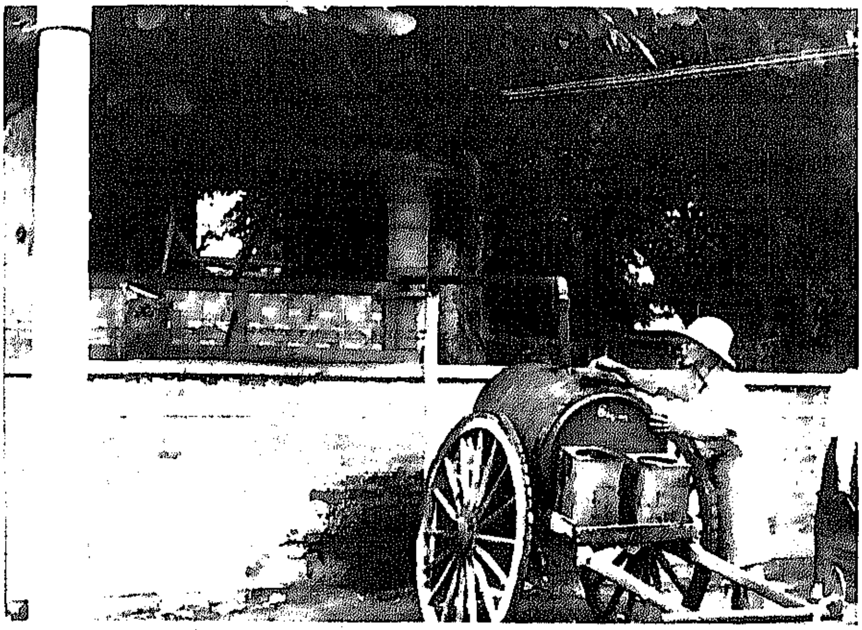
Japan International Cooperation Agency



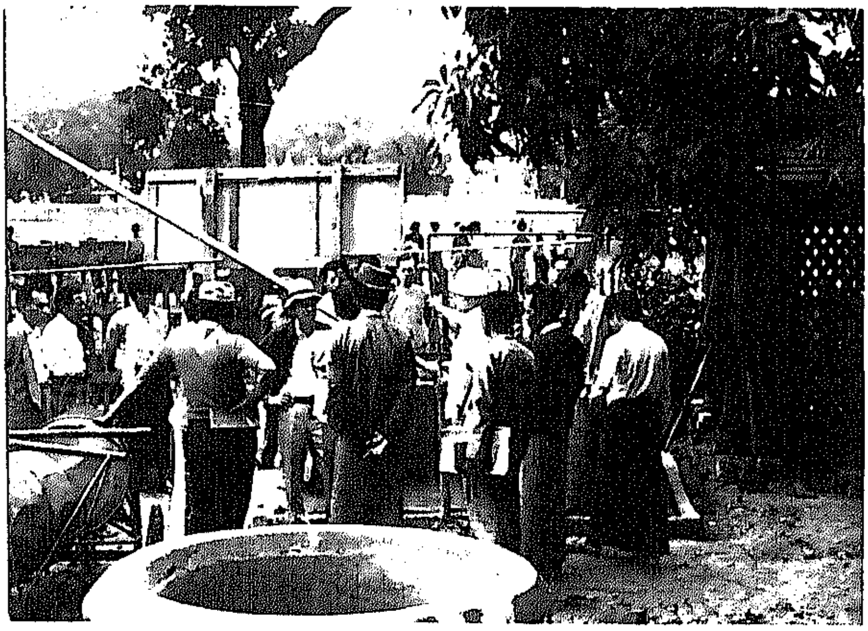
LOCATION MAP S= 1/5,000,000
Shwebo
Monywa
Mandalay
Pakokku
Myingyan
Thazi
Yenangyaung
Pyawbwe
Yamethin
Magwe
Taungdwingyi
Pyinmana
Prome
Toungoo
Henzada
Tharrawaddy
Pegu
Bassein
RANGOON
Bhamo
Maymyo
Kyaukse
Chittagong
Akyab
Kyaukpyu
Sandoway
Thayetmyo
Allanmyo
Shwegyin
Thaton
Pyapon
Maubin
Myaungmya
BAY OF BENGAL
GULF OF MARTABAN
MOUTHS OF THE IRRAWADDY
CHINA
BURMA
THAILAND
0 50 100 150 200 Kilometres



(Mandalay-Shwebo)
110Km
Shwebo
(Shwebo-Manywa)
150Km
Chinrdwin
Monywa
Mandalay
(Thazi-Tandalay)
180Km
Pakokku
(Monywa-Pakokku)
110Km
Pagan
(Pakokku-Pagan)
45Km
Thazi
(Pyawbwe-Thazi)
65Km
Pyawbwe
(Pyinmana-Pyawbwe)
110Km
Yemangyaung
Yamethin
Magwe
(Pagan-Magwe)
160Km
Taungdwigyi
Pyinmana
110Km
(Magwe-Prome)
240Km
Toungoo
Prome
(Rangoon-Toungoo)
280Km
CHINA
BURMA
290Km
THAILAND
Pegu
Rangoon

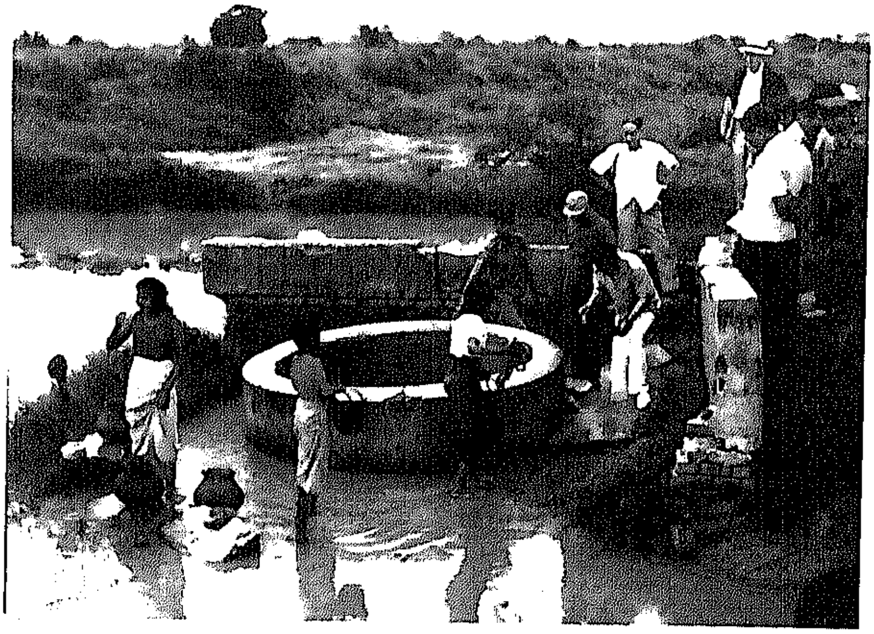


Water-selling bullock-cart is being supplied by a private well in Pyinmana.

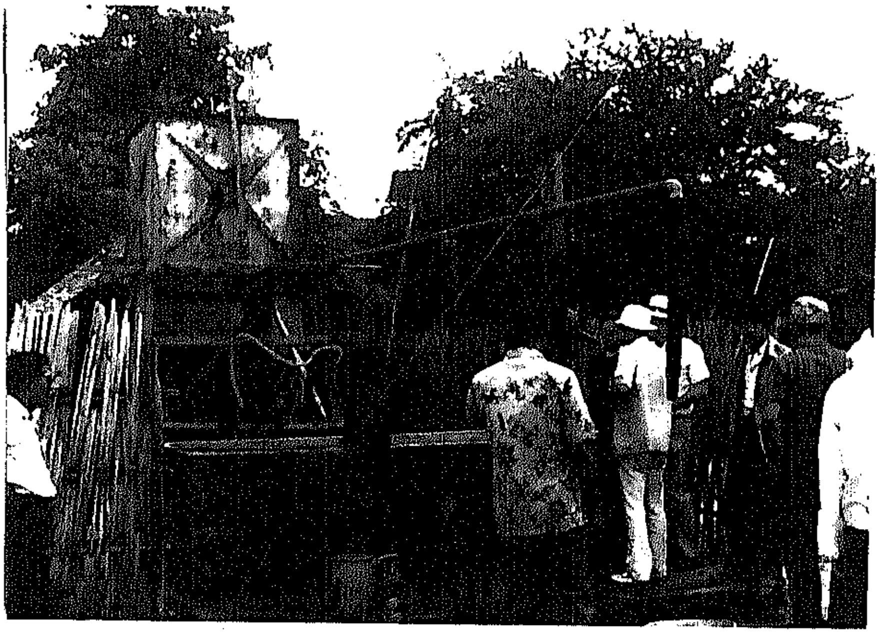


Well survey in Pyinmana.

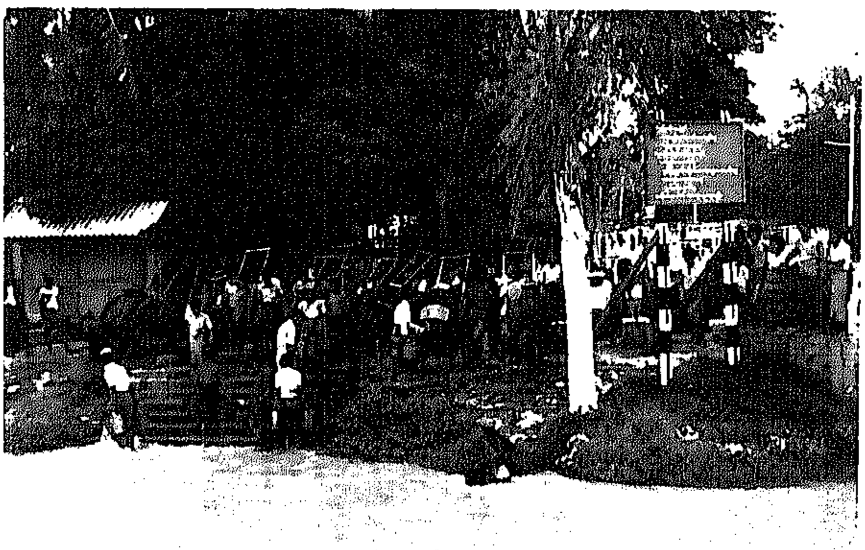
Water source of Yamethin.



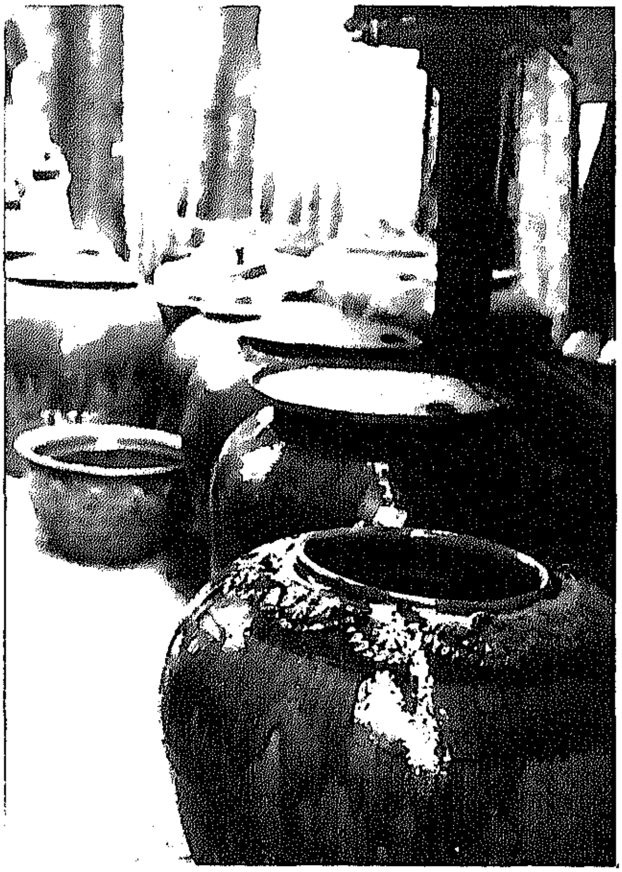
Water quality test in Pyawbwe.



The public well in Thazi.

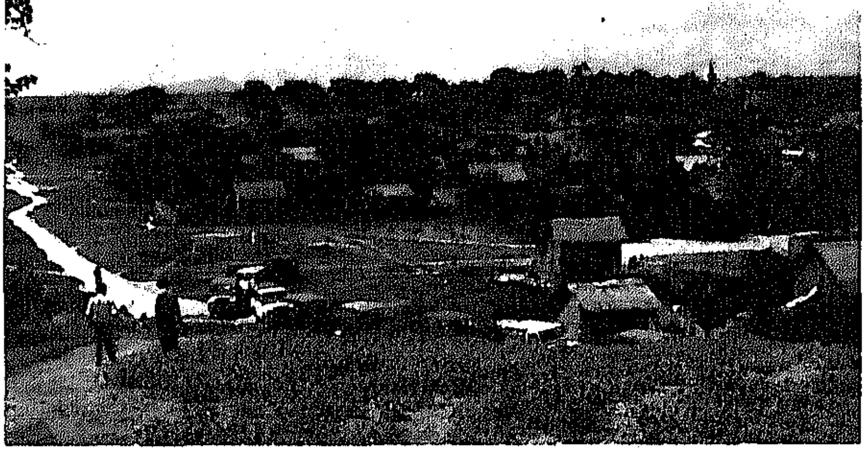


Water taking site on a canal in Shwebo.



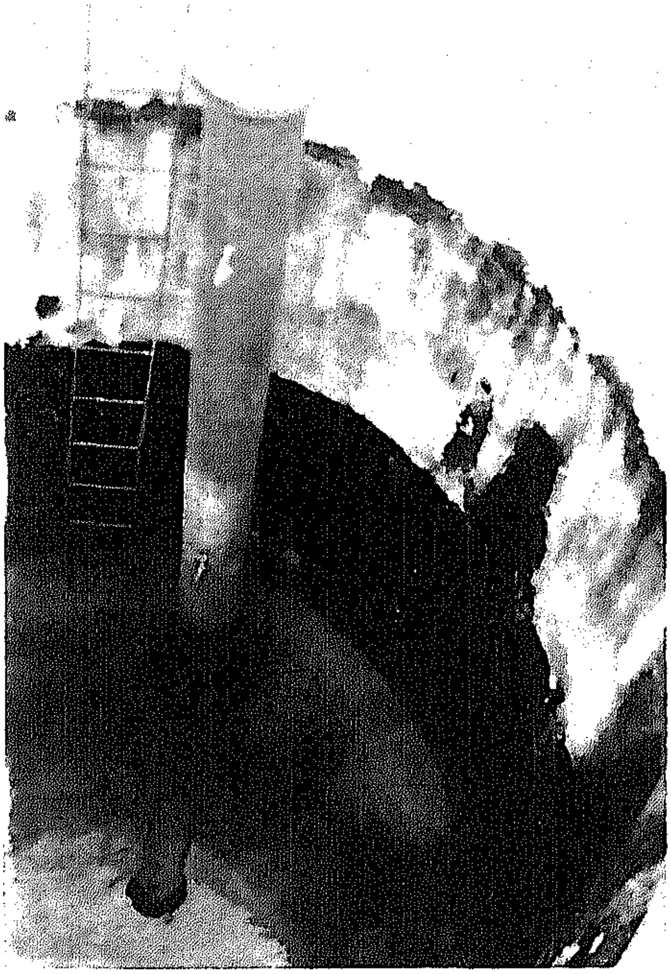
The stored rainwater for drinking in Shwebo.

Inhabitants gathered around Dug Well in Pakokku

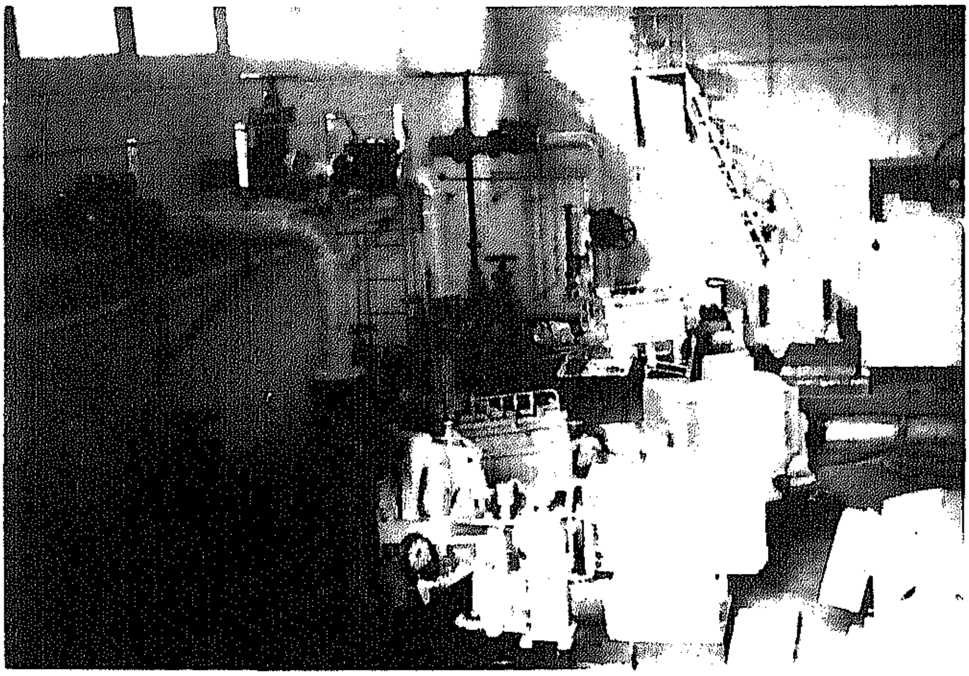


Pakokku new residential area.

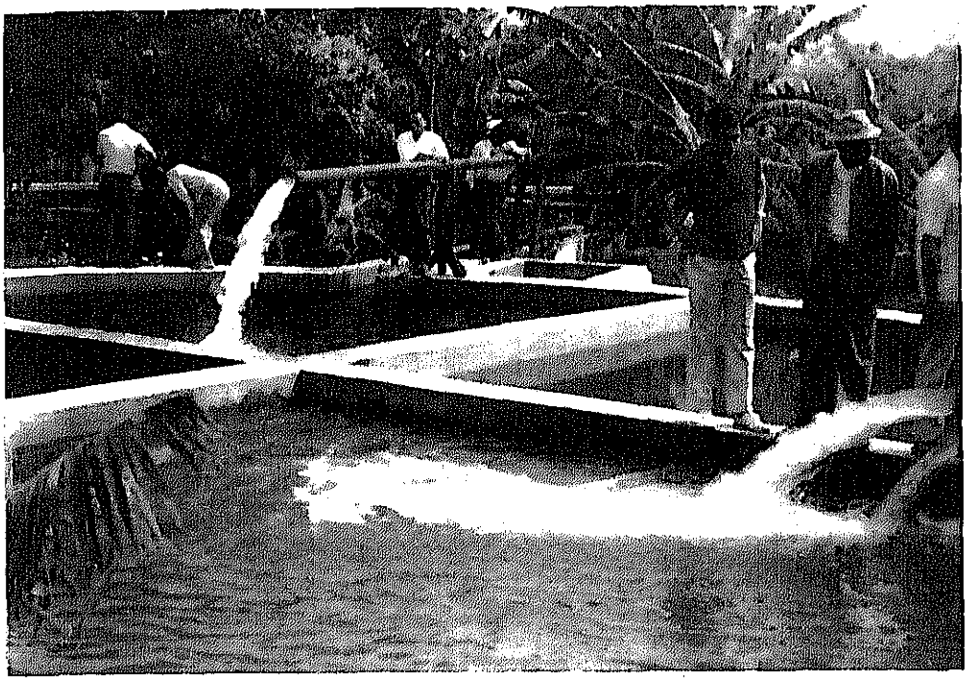
Public stand in Taungdwingyi.



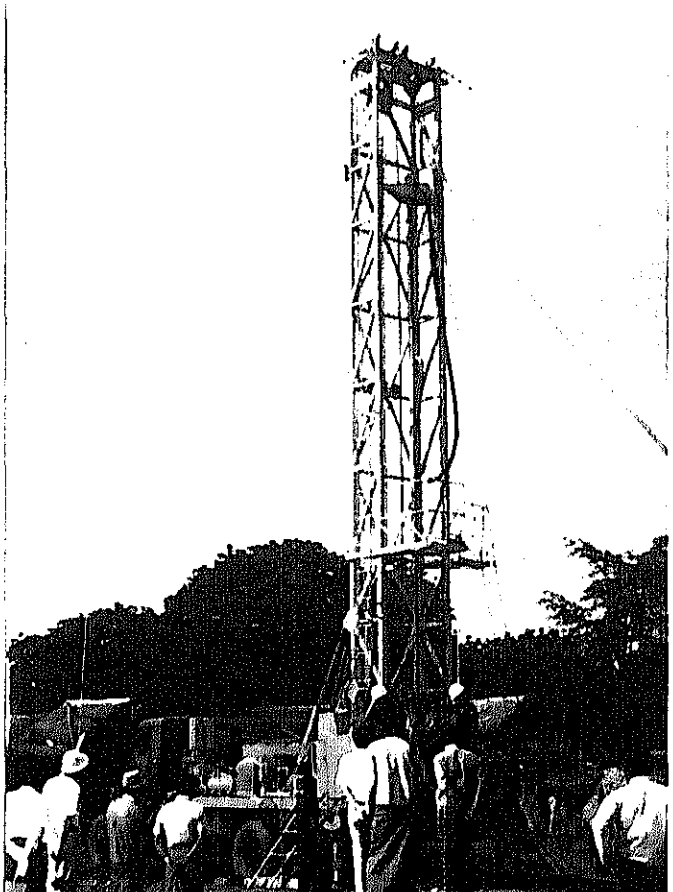
The well facilitated along the Pin Chaung River in Yenagyaung.



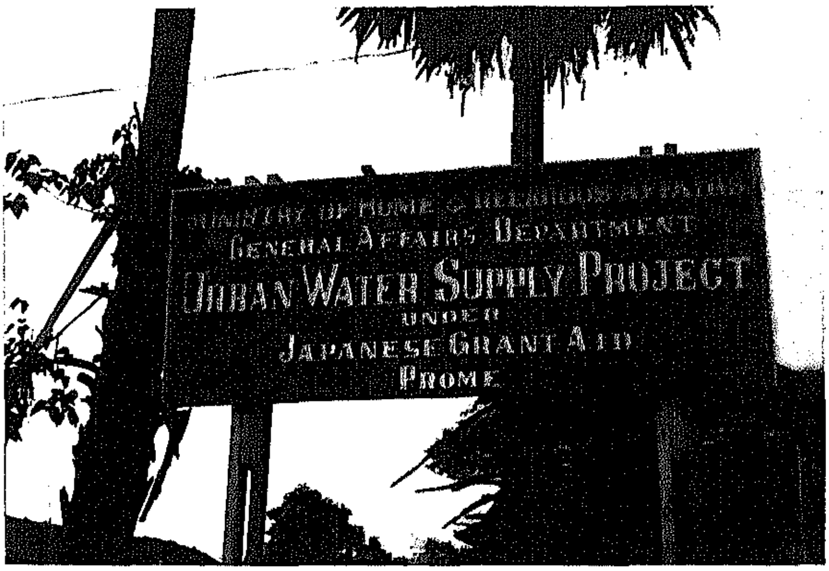
Pumping station equipped for the above well.



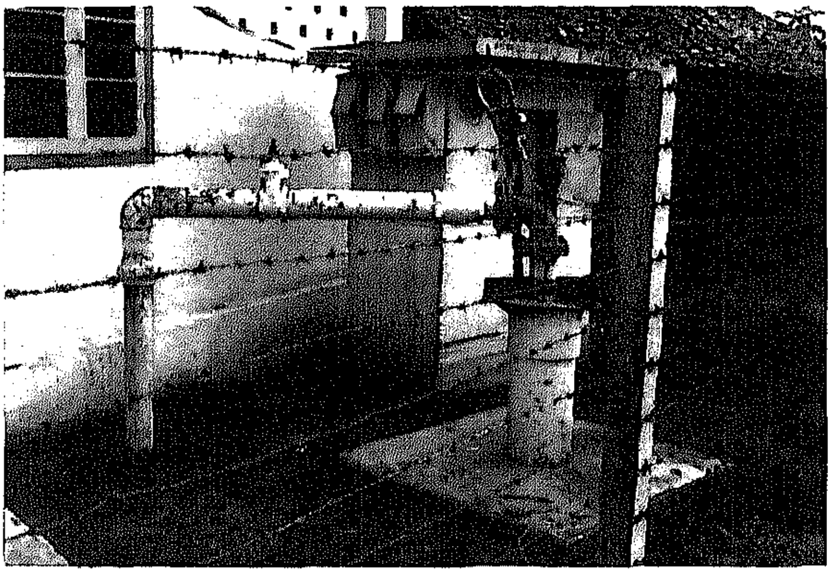
Groundwater in being centered from the wells accomplished by the Project in Magwe.



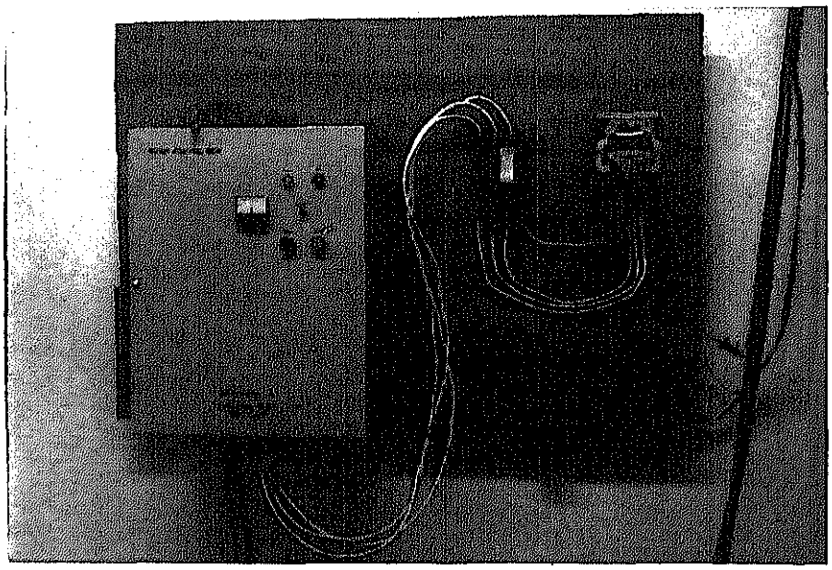
Deep Well under drilling in Magwe.



The signboard of the project office in Prome.



The accomplished well and control room in Prome.



Control Panel

Summary

1. In Burma 24% of the total population, i.e. 8.6 million, live in urban areas and of these only some 3.6 million are served with water supplies giving an overall water distribution factor of 10%. Of the country's 288 towns, 63 have small scale water supply facilities. However, nearly all these date back to the pre-war period in construction and their capacity is small and the quality of the water delivered is also a problem. Areas and towns without public water supply facilities use shallow wells, rivers and ponds as sources of water for their daily needs. In the hot regions especially, the sources of water are extremely scarce, their quality is suspect and the incidence of water spread diseases is very high. In order to improve these circumstances the Burmese Government is giving the development of drinking water supplies an urgent priority.

2. In Burma, the development of water supplies for regional towns is the responsibility of the General Affairs Department of the Ministry of Home & Religious Affairs, and developments, especially in the towns in the dry zone that are in bad condition have been given priority. In 1981 the Burmese Government with the aid of a grant from the Japanese Government, carried out a drinking water development scheme in two towns, Magwe and Prome. They are hoping to carry out similar projects in a number of other towns and to this end have submitted a request to the Japanese Government for a grant. In reply the Japanese Government, through the agency of JICA, dispatched a survey team to earry out the preliminary study and followed this up by carring out a basic design study.

3. The purpose of the present study is to examine the basic design study for the design of drinking water supplies for the towns listed below, and proposals for additional assitance with materials and equipment in regard to the projects previously undertaken in Magwe and Prome.
The towns under consideration in the basic design study are as follows:-

(1) Pyinmana	(2) Yamethin	(3) Pyawbwe
(4) Thazi	(5) Shwebo	(6) Monywa
(7) Pakokku	(8) Yenangyaung	(9) Taungdwingyi

4. The design criteria in regard to drawing up proposals for the drinking water supply system are as follows:-

(1) The target year is to be 1990

(2) a. water demand/person/day 70 litres (15 gals)

b. max. water demand/person/day = a + 50%

i.e. 105 litres (22.5 gals)

(3) In principle deep wells are to be utilized as water sources.

(4) The water supply and main distribution pipes (min. 75mm) are to be of steel.

(5) The internal pressure acting on the end of the pipe is to be 4m (0.4Kg/cm)

(6) Elevated water tanks are to be built of FRP panels, underground storage tanks are to be of steel reinforced concrete, capacity is to be based on their respective daily demands for either 30 min. or 2 hrs.

5. An outline of the design for the 9 towns is given below.

Summary of Each Town

	Item \ Town	Pyinmana	Yamethin	Pyawbwe	Thazi	Shwebo	Monywa	Pakokku	Yenan-gyaung	Taung-dwingyi
Condition of the Towns	Division	Mandalay	Mandalay	Mandalay	Mandalay	Sagaing	Sagaing	Magwe	Magwe	Magwe
	Distance from Rangoon (km)	320	400	410	450	640	590	520	420	360
	Number of Wards	6	5	8	7	10	18	15	14	10
	Altitude above Sea Level (m)	92 ~ 122	200	200 ~ 230	214	92 ~ 122	75 ~ 120	53 ~ 69	75 ~ 100	83
	Area of Town Proper (km^2)	5.7	7.7	6.4	2.4	6.1	21.9	9.6	33.0	6.6
	Temperature Upper Summer Lower Winter	42~15°C 38~8°C	max 42°C min 29°C	max 35°C min 20°C	42~17°C 31~5°C	max 43°C min 28°C	42~21°C 29~12°C	max 43°C min 10°C	max 44°C min 27°C	44~37°C 30~33°C
	Annual Rain Fall Ave. (mm)	900 ~ 1,850	609 ~ 1,063	172 ~ 1,180	480 ~ 1,011	460 ~ 1,138	315 ~ 1,070	173 ~ 774	388 ~ 483	458 ~ 1,390
Summary of Planning	Existing Population ('83)	51,275	22,598	23,834	18,434	48,920	105,096	70,265	71,475	38,563
	Increasing Rate of Population (%)	1.8	1.4	2.2	1.9	2.1	2.5	2.2	1.6	2.0
	Served Population ('91)	59,200	25,300	28,400	21,400	57,800	128,000	81,800	81,200	45,200
	Total Water Demand (m^3/day)	6,200 (1.36)	2,700 (0.59)	3,000 (0.66)	2,300 (0.51)	6,100 (1.34)	13,500 (2.97)	8,600 (1.89)	8,500 (1.87)	4,800 (1.06)
	Discharge Rate per Well (m^3/day)	600	600	200	500	700	1,400	1,200	1,590	700
	Number of Proposed Wells	10	5	15	5	9	10	7	* 5	7

* Infiltration Gallery Well
(   ) Million Gallon

6. The yearly maintenance costs of these facilities is estimated to be Kyats 8,400,000 (250,000,000 yen). The works are separated into two stages, i.e. the construction period after the exchange and completion of contracts is to be in a 15 month 1st stage and a 36 month 2nd stage.

7. With the carrying out of this project, it becomes possible to provide a safe, clean, steady supply of drinking water for the people of the various towns and in addition to generally improving the quality of life for the people, it will also facilitate greater health and hygiene so that some stimulation of regional town development and expansion can be expected.

ABBREVIATION

ADB - Asian Development Bank

UNICEF - United Nations Children's Fund
(former United Nations International Children's Emergency Fund)

EPC - Electric Power Corporation

DWSSD - Drinking Water Supply and Sanitation Decade

GAD - General Affairs Department

IRC - International Reference Center

MCDC - Mandalay City Development Committee

MOC - Myanma Oil Corporation

RCDC - Rangoon City Development Committee

TDC - Township Development Committee

WHO - World Health Organization

EC - Electrical Conductivity (μS/cm)

gpcd - gallon per capita (per) day

1 pcd - liter per capita (per) day

UNIT

1 in = 25.4 mm

1 ft = 12 in = 30.48 cm

1 mile = 5,280 ft = 1.609 km = 1,609 m

1 acre = 43,560 ft^2 = 4,046.9 m^2 = 0.00405 km^2

1 $mile^2$ = 640 acre = 2.59 km^2

1 gal (1 imp. British) = 4.546 Liters = 0.00455 m^3

CURRENCY

1 Kyat = 100 pyas = 30 Yens

1 US Dollars = Kyats 8.3

CONTENTS

CHAPTER 1

BACKGROUND OF THE PROJECT

1.1 General Situation

The Socialist Republic of the Union of Burma faces the Indian Ocean to the South and borders the People's Republic of China to the northeast, Thailand and Laos to the southeast and Bangladesh and India to the west. The country is made up of some 678,000 square kilometers of land, and has a population of some 36 million, which is increasing annually at the rate of 2.2% for the year 1982/83. The Union of Burma is comprised of 7 States and 7 Divisions which are subdivided into 314 Tonwships made up of 288 Towns, 13,751 Village-Tracts and 65,327 Villages in all.

In the country about 24% of the total pupulation live in urban areas. However, only 10% of the population is served with any kind of water supply. 63 of the 288 towns have supply facilities at present, almost all of which were constructed prior to the Second World War.

Except in Rangoon and Mandalay, local towns, even if there is some kind of drinking water supply, have no facilities for chemicals for water treatment or sterilization and as such the quality of the water supplied does not seem to be really adequate for drinking purposes, i.e. unhygienic water is being supplied. Usually, the quantity of water supplied is also insufficient and the water is therefore inevitably supplied at set times for a limited period; sometimes as little as 1 or 2 hours a day, or even once every two days, etc.. In areas where water supply facilities are not available or are inadequate, people rely on private water sellers, distributing it by means of a drum carried on a bullockcart, for their needs; but, such vendors often take raw water from wells or surface water from the fields, rivers, canals, ponds, or even puddles. Furthermore, there are many areas where such ground water registers fairly high salinity values making it unsuitable for drinking purposes and so people have to discriminate to some degree on the suitability of water; reserving river and rain water for drinking and ground water for washing and other such uses, however, the general circumstances surrounding water utilization are not particularly good.

At present, the development of domestic water supply facilities in Burma is being run by the General Affairs Department (GAD) of the Ministry of Home and Religious Affairs, in cooperation with Township Development Committees (TDC). However, development projects are tending to stagnate because of difficulties with foreign investment, lack of technical expertise and scarcity of materials and equipment. Accordingly less than 6% of the city population benefited from new drinking water supplies in the 5 year period from 1977 to 1981.

1.2 Request from the Burmese Government

The Japanese Government received a request from the Burmese Government regarding Grant Aid for the towns of Prome and Magwe in respect of help with additional materials and equipment, (phase 1) and the carrying out of a Basic Design Study for the Development of Drinking Water for and a further 8 towns, (phase 2).

Phase 1 - Prome and Magwe

In regard to these towns, the Japanese Government, upon receipt of a request from the Burmese Government in October 1980, carried out an Urban Water Supply Project Study and based on the subsequent results of this study assited by supplying part of the materials and equipment.

The Burmese Government prepared the detailed design and undertook the construction work which is presently being carried out with the materials and equipment supplied above. However, because of the lack of some materials incidental to the main water supply line and auxiliary water reservoir facilities, finalization of the project is far from certain.

Consequently, to enable speedy completion of the project works presently under construction a request for additional materials and equipment has been submitted.

Phase 2 - 8 Towns

The Burmese Government as a matter of National Policy ranks drinking water supply works as a major priority, and in the Burmese Government's IDWSSD plan, (Drinking Water Supply and Sanitation Decade), a target figure of 50% is given for water supply coverage of the country for 1990.

By way of accomplishing their plan, the Burmese Government has selected from its 288 towns some 8 towns in urgent need of water supply facilities and has requested assistance with the carrying out of a basic design study and supply of related materials and equipment.

1.3 Dispatch of Preliminary Survey Team

Upon receipt of the Burmese Government's request, the Japan International Cooperation Agency (JICA) decided to carry out a preliminary survey in order to determine more clearly the scope of the request and for this reason a survey team was sent to Burma for the period between the 17th of June and 1st of July 1984.

The survey team carried out an actual site survey, in addition to clarifying the contents of the request, and they exchanged views with officials of GAD in regard to the possibility of developing water supply projects in local areas, especially those of the hot dry zones in the centre of Burma.

After visiting the 8 towns mentioned in the Burmese Government's request, the survey team could consider fully the degree of urgency and scale of such work, and it was subsequently decided to recommend that two towns, Toungoo and Pegu be omitted and three other towns Yamethin, Yenangyaung and Taungdwingyi be added. (Please refer to the attached Minutes of the Discussion of the Preliminary Study).

1.4 Basic Design Study

To complete a basic design study based on the previous preliminary survey, with the object of providing assistance to Prome - Magwe and the revised 9 towns, site surveys were undertaken in the 73 day period from September the 8th to November the 18th 1984, after which a 3 month analysis was carried out.

1.4.1 Survey Towns

The towns surveyed in the basic design survey are as follows:-

(a) PAKOKKU	(b) THAZI	(c) MONYWA
(d) PYINMANA	(e) PYAWBWE	(f) SHWEBO
(g) YAMETHIN	(h) YENANGYAUNG	(i) TAUNGDWINGYI
(j) PROME	(k) MAGWE	

1.4.2 Objectives of the Study

In order to present proposals about additional supplies of materials and equipment in regard to Prome and Magwe, and draw up anew and make clear in concrete terms, proposals in regard to Japanese grant assisted water supply facilities for the 9 towns, the basic design survey was carried out with the following works in mind:-

① To estimate the potential capacity of available aquifers

② To project future water demand

③ To prepare a Ground Water Development Plan

④ To prepare a Water Supply System Development Plan

⑤ To evaluate the project

⑥ To prepare a Specification of Materials and Equipment necessary for the project

⑦ To prepare and price a Bill of Quantities for the necessary materials and equipment

⑧ To prepare concrete proposals in regard to a Japanese Grant Aided Project

The field survey has been carried out in primary and secondary stages. In the primary stage the existing and future conditions of each town have been assessed in relation to water supply planning and each town is now understood in terms of the present state of existing water sources and facilities; as well as hydrogeological conditions which indicate sites suitable for geophysical investigation in the secondary stage. Such investigations are to confirm optimum water sources so that they can be exploited when the plan is implemented.

In the secondary stage, a basic design for water supply systems and facilities to each of the respective towns has been carried out in respect of the studies and is presented along with an estimate of costs for the necessary materials and equipment to be supplied.

1.4.3 Survey Procedure

The investigations were conducted in accordance with the flow chart show in Fig. 1.4.3.1.

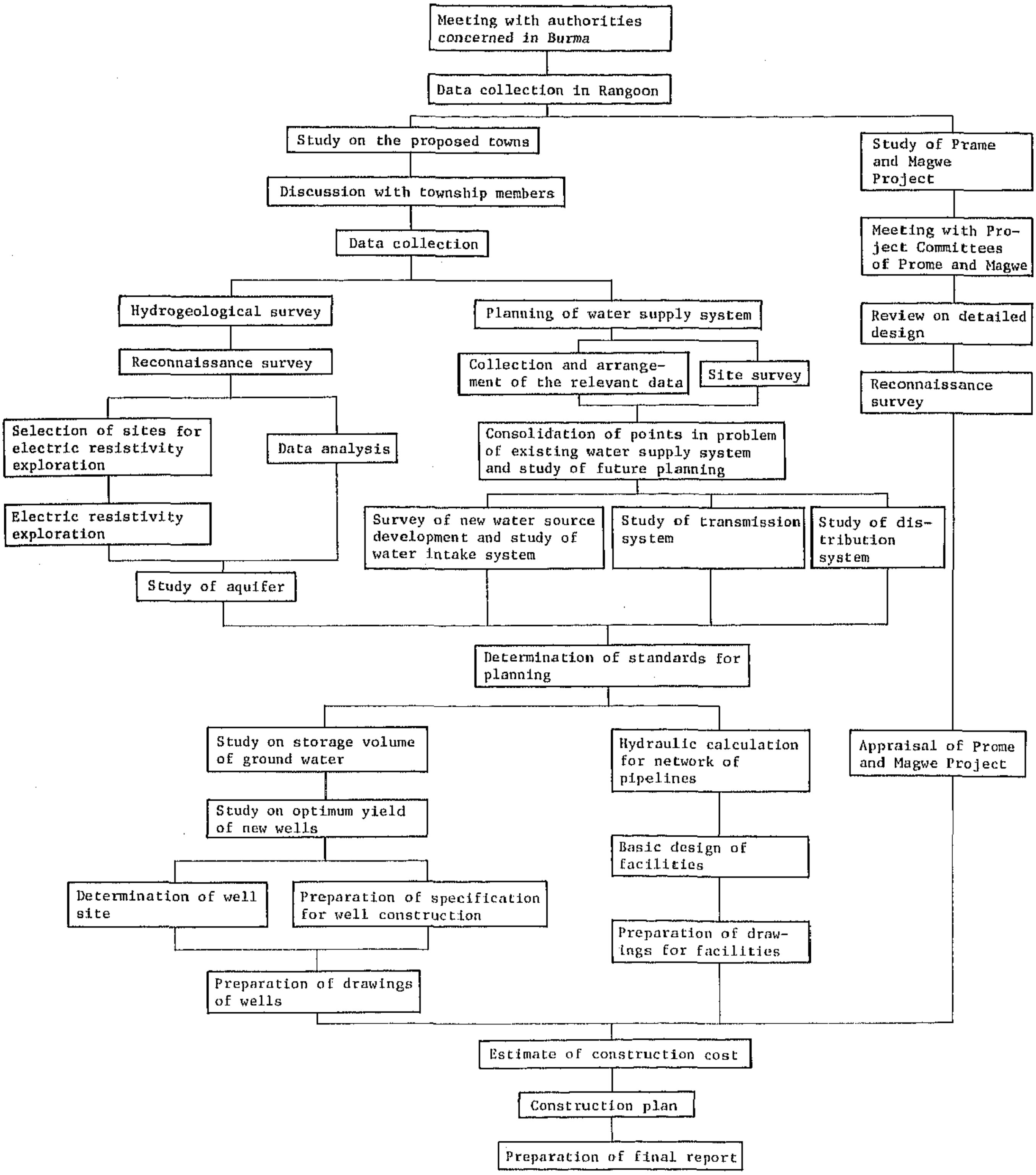


Fig. 1.4.3.1 Flowchart for Basic Design Study

CHAPTER 2

WATER SUPPLY WORKS IN THE UNION OF BURMA

2.1. General Features of the Union of Burma

2.1.1 Overall Outline

Burma at present is officially entitled "The Socialist Republic of the Union of Burma". It has a land area of some 676,000 sq.Km., roughly 1.8 times that of Japan. The climate is monsoonal in that the hot season is from the end of February to the middle of May, the rainy season is from the end of May to the middle of October and the cool season is from the end of October to the middle of February.

In the capital of Rangoon the average monthly temperature varies between 23°C and 27°C for the year, which is not really a very large temperature fluctuation, however, there is a particularly high rainfall of about 700mm a month in the rainy season and conversely almost no rain at all in the cool season.

The population, presently over 36 million had an annual population growth rate of 2.01% for the year 1982/83 which seems lower than that of other southeastern countries.

The Burmese account for 60% of the population, the rest are made up of some 50 races such as the Karen, Shan, Kachin and Mon etc., which means that the country is truely multi-racial in character.

Language falls into two large classificiations, Tibet-Chinese and Mon-Khmer. As Burmese is practically understood throughout the country, it is used as the official language. English is a left-over from the British Colonial period, but as it is now viewed as an international language of great practical important, its study is being encouraged to a widespread degree throughout the country.

Geographical features consist of the Kachin hills to the north, the Shan plateau to the east, the Chin hills and the Arakan mountains to the west and a central lowland area. The river Irrawaddy flows from the north to the south passing through the central lawlands until it discharges into the Indian Ocean, the downstream area a of which forms a huge delta. Also, to the east, running near the Thai border is the river Salween which takes a course parallel to that of the river Irrawaddy.

2.1.2 The Industrial and Economic Situation

Industry in the Socialist Republic of the Union of Burma is carried out by three sectors, the State, Private and Cooperatives.

Depending on the kind of industry, the percentage made up by each of the three sectors varies, for example, for the fiscal year 1983/84, the percentage share of actual production figures for state run businesses came to 99.9% for electrical power, 98.7% for social administration, 88.8% for mining including oil, 81.5% for construction, 59% for manufacturing, whereas, in the area of agriculture the figures were respectively 0.3% for the state, 2.6% for cooperatives and 97.1% for private. Similar figures for livestock and fisheries were 1.8%, 1.3% and 96.9%; for forestry i.e. timber 37.8%, 4.4% and 57.8%; for transport and freight 37.0%, 5.8% and 57.2%; and for trade 46.2%, 9.2% and 44.6%; etc., which show that the private sector holds the biggest share in these particular fields.

Further, agricultural production depends by and large on land owning, tax paying farmers, especially in connection with produce for export such as rice, sugar cane, beans, cotton, tobacco and jute etc., which is bought up by the government; other produce such as groudnuts, sesame, chilli, sunflowers, garlic and potatoes etc., are distributed and sold on the domestic market by the cooperatives.

Within cooperative organizations are central, township and primary cooperatives, as well as various other industrial cooperatives, including consumers and the army, etc., giving some 20 kinds in all; commerce and brokerage, industry and manufacturing, distribution and sales are their main concerns; and their respective overall turnovers were 540, 186 and 794 million kyats for 1983/84.

According to the statistics for the 1983/84 fiscal yer, agricultural produce accounted for 666.6 million yen, 37.6%, of the gross national product of 1.77 billion yen, coming just behind industry with its 771.1 million yen, 43.5%. For the 1974/75 fiscal year with a gross national product of 0.6253 billion yen, agriculture accounted for 42.6% and industry 42.3%, which means that over a 10 years period the gross national product has increased 2.8 times, agriculture 2.5 times and industry 2.9 times in scale.

In regard to the gross national product, mining accounts for some 1.7%. Within this figure crude oil at the rate of 9.8 million US barrels and natural gas at some 490 million cubic metres (1983/84) is produced; which is just about sufficient to meet domestic needs. However, coal production is extremely low.

Other than this, mining yields gems and turgsten etc., the production of which, especially as regards jade and emeralds, the Burmese Government is controlling for posterity. Also, tungsten prior to the war satisfied 85% of British needs and even now, more than 800 tons of 65% pure tungsten is produced a year.

Prior to the war the balance of trade was in the black (1941/42-1947/48), however, after the fiscal year 1960/61, imports exceeded exports and the deficit for 1981/82 was 2,160 million Kyats, and for the 1983/84 fiscal year 2,140 million Kyats. The main reason for this seems to be that price of its principle agriculture produce fell on the international market. Also, Burma receives imports from Japan, the EEC, North America and Canada and North West Europe etc., whilst its main countries for export are Bangladesh, Sri Lanka, Japan, the EEC and various African countries etc.,

Industrial production overall was above that of agriculture in monetary tems, however, a large number of improvements are still found to be wanting. To give examples of the production output of some of the various products, we have:-

Sugar (49,000 tons): cotton yarn (14,000 ton): tobacco (2,740 mil.cigs.): cement (370,000 tons): paper (22,800 tons): bamboo pulp (6,400 tons): glass sheet (8.000 tons): kerosene (7.7 mil. gals): florescent tubes (400,000 off) cars (2,115 off): bicycles (20,000 off): water pumps (6,350 off): fertilizer (151,800 tons): etc..

Further, production and growth for Burma as a whole are given in table 2.1.2.1.

Table 2.1.2.1 Production and Growth for Burma as a Whole

(in Million Kyats)

ITEM	1979/80	1982/83	1983/84
goods	411.7	544.4	590.5
services	80.7	114.2	118.2
trade	121.6	151.4	160.0
TOTAL	614.0*	810.0*	868.6*
industrial use	260.7	345.5	371.4
net output	353.3	464.5	497.3
imports	42.0	65.7	57.3
exports	26.8	30.0	35.9

(in Kyats)

ITEM	1979/80	1982/83	9183/84
per capita output	1,864,0	2,316.0	2,435.0
net output	1,073.0	1,328.0	1,394.0
income	1,119.0	1,430.0	1,454.0
consumption	880.0	1,128.0	1,151.0
investment	224.0	287.0	284.0
output per worker	4,649.0	5,710.0	5,992.0
net output per worker	2,675.0	3,275.0	3,430.0

2.2. Hydrogeology of the Union of Burma

2.2.1 Climate

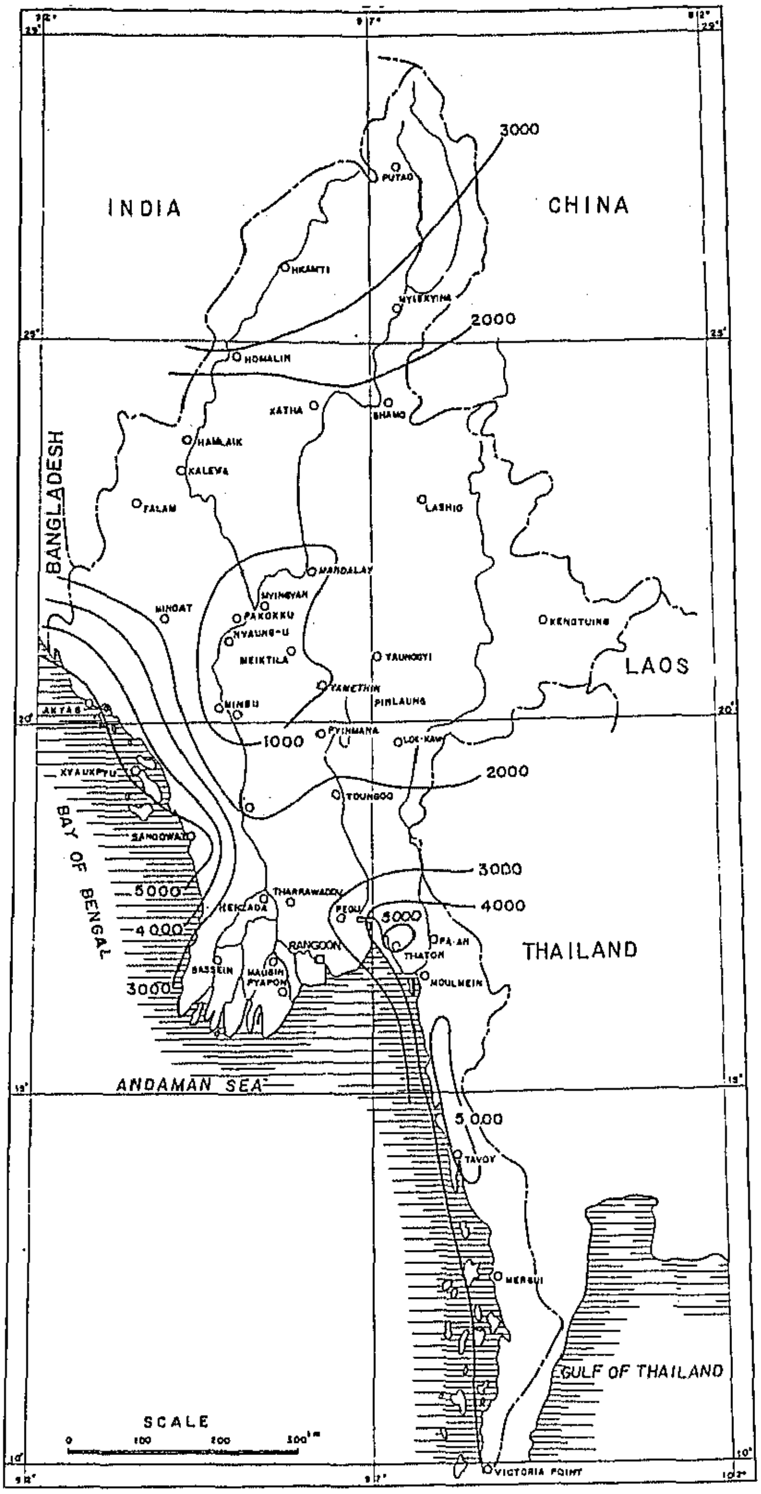
The land of Burma belongs to a monsoon area. However, its climate varies remarkably in different regions due to the presence of the Arakan Mountain Ranges. Damp air from the Bay of Bengal strikes against the Arakan Mountain Ranges and then arid air flows into the inland of Burma. For this reason, the inland regions of Burma have become an arid area. Therefore, the Burmese land is roughly classified into a monsoon area and a semi-arid area.

The Burmese Meteological Agency is issuing a yearly rainfall report. The annual mean precipitation map of Burma, which has been prepared based on this report, is shown on Fig. 2.2.1.1. This figure indicates that the yearly precipitation in the Arakan Mountain Ranges and the Tenasserim Mountain Ranges is more than 3,000 mm, in the central lowland region between these two mountains less than 3,000 mm and in the central Burma region less than 1,000 mm.

The yearly precipitation in each town is shown on Table 2.2.1.1. In general, the evaporations in these towns are comparatively low. However, these are higher in the inland region and lower in the northern and southern regions.

According to Fig. 2.2.1.1. and Table 2.2.1.1., it is understood that these towns included in this project belong to mostly semi-arid areas. The precipitations in Pyinmana and Taungdwingyi are 1,000 to 1,300 mm a year and those in Pakokku and Yenangyaung 440 to 560 mm a year.
In other towns they are 730 to 870 mm a year.

The evaporations in Monywa and Mandalay of semi-arid areas are about 2,000 mm a year and that in Pegu of a monsoon area about 1,450 mm a year.



Compiled from Meteorological Department Data

Fig. 2.2.1.1 Rainfall Distribution in Burma (mm)

Table 2.2.1.1 Rainfall and Evaporation of each Town

(in mm)

Town Month	1	2	3	4	5	6	7	8	9	10	11	12	Total	
Pyinmana	8.4	2.8	4.6	39.4	149.8	193.4	232.5	237.7	216.5	144.7	54.5	6.5	1,298.8	1874 - 1983
Yamethin	10.6	1.2	6.6	22.7	140.5	91.0	98.7	133.5	180.6	105.7	68.1	9.4	868.6	1973 - 1983
Pyawbwe	14.4	0.2	12.9	28.2	120.2	112.3	94.8	117.6	171.0	116.8	59.4	3.5	851.3	1974 - 1983
Thazi	9.4	2.2	6.1	17.3	91.1	119.5	93.6	91.3	140.4	135.7	55.4	5.1	767.1	1974 - 1983
Shwebo	-	1.5	1.0	22.4	86.2	161.7	83.4	158.4	169.0	133.0	41.2	11.3	869.1	1978 - 1983
Monywa	3.1	0.2	3.1	16.2	105.7	92.8	73.1	121.4	135.1	121.7	53.5	5.6	728.5	1974 - 1983
Pakokku	-	-	0.9	8.5	41.0	92.7	22.0	51.3	144.7	114.0	79.1	4.3	558.5	1980 - 1983
Yenangyaung	0.8	-	-	3.4	6.8	37.3	101.4	107.8	113.3	42.9	16.1	8.4	438.2	
Taungdwingyi	6.7	0.4	1.4	12.5	151.1	167.5	132.8	172.7	203.0	104.4	50.3	5.3	1,008.1	1974 - 1984
Monywa	106.1	140.3	201.7	234.3	228.5	201.2	205.8	174.6	142.3	164.0	108.4	102.2	2,009.4	
Mandalay	90.6	157.9	215.3	239.7	239.5	205.6	212.2	177.9	168.1	159.5	90.8	83.8	2,040.9	
Pegu	117.8	122.0	159.9	146.1	131.7	88.7	96.6	103.7	129.6	140.9	97.8	111.4	1,446.2	

2.2.2 Hydrogeology

The geological structure of Burma comprises of mainly the Shan highlands of old bed rocks of Palaeozoic strata and Granites prevailing over the eastern region and the Arakan upheavals of Palaeozoic strata or Certaceous Strata prevailing over the western region. These strata run almost to the south and north. These highlands and upheavals were created in the period of the Himalayan orogenic movements and at the same time a great number of faults and foldings in strata occured.

The central lowland region encircled by the Shan highlands and the Arakan upheavals was cut by the north-south tectonic line at both sides. The cut narrow portions have become gravens and are so called the Central/Cenozoic/Belt. This belt comprises of almost Cenozoic sedimentary rocks. The summarized geological structure of Burma is shown on Fig. 2.2.2.1. There are the following four (4) uplifts and three (3) basins in the Central Cenozoic Belt.

1) Uplifts - Kunon Ridge Uplift, Wuntho Mass Uplift, Sanlingyi Uplift and Pegu Yoma Uplift
2) Basins - Chindwin Basin, Minbu Basin and Irrawaddy Embayment

Also the geological structure of the Central Cenozoic Belt are mainly classified as follows.

1) Pegu Formation (The Oligocene and the Middle and Lower Miocene Formations)
2) Irrawaddy Formation (The Upper Miocene or the Pliocene Formations)
3) Diluvium
4) Alluvium

The Pegu formation is an alternate layer of sandstone and shale. This formation comprises of continental sediments in the northern region and marine sediments in the southern ragion. These sediments are in a semi-consolidated state and very poor in water-bearing capacity. The Irrawaddy formation comprises of materials brought by the Irrawaddy River and its thickness is estimated approximately 3,000 m. The Irrawaddy formation consists of an alterante layer of sand and clay, of which sand is dominant. This formation is a major water-bearing layer in Burma.
The property of this layer is that medium to coarse sands are main and ferruginous in color and it contains some quartz particles. In addition it contains fossiles of terrestrial and quatic vertebrates, mostly mammalian, and silicified woods, by which the geological age can be determined. The Irrawaddy formation, which is always in unconformity with the lower Pegu formation, overlies the Pegu formation.

In Burma it is difficult to produce groundwater from the Mesozoic and Palaeozoic strata, igneous rocks and semi-consolidated rocks of the Pegu formation because the water-bearing capacity of these layers is quite inferior. Meantime, it is possible to produce groundwater in special conditions such as that existing in fissures or faults of layers. In case of the Irrawaddy formation and the unconsolidated strata of Diluvium and Alluvium, groundwater can be obtained from a water-bearing layer of consisting of sands and gravels. Depths and thicknesses of the water-bearing layers are different remarkably in localities. Most volume of groundwater in the Irrawaddy formation often exists in an artesian state and there are some places where groundwater is in an artesian flowing state. However, the groundwater quality is rather poor.

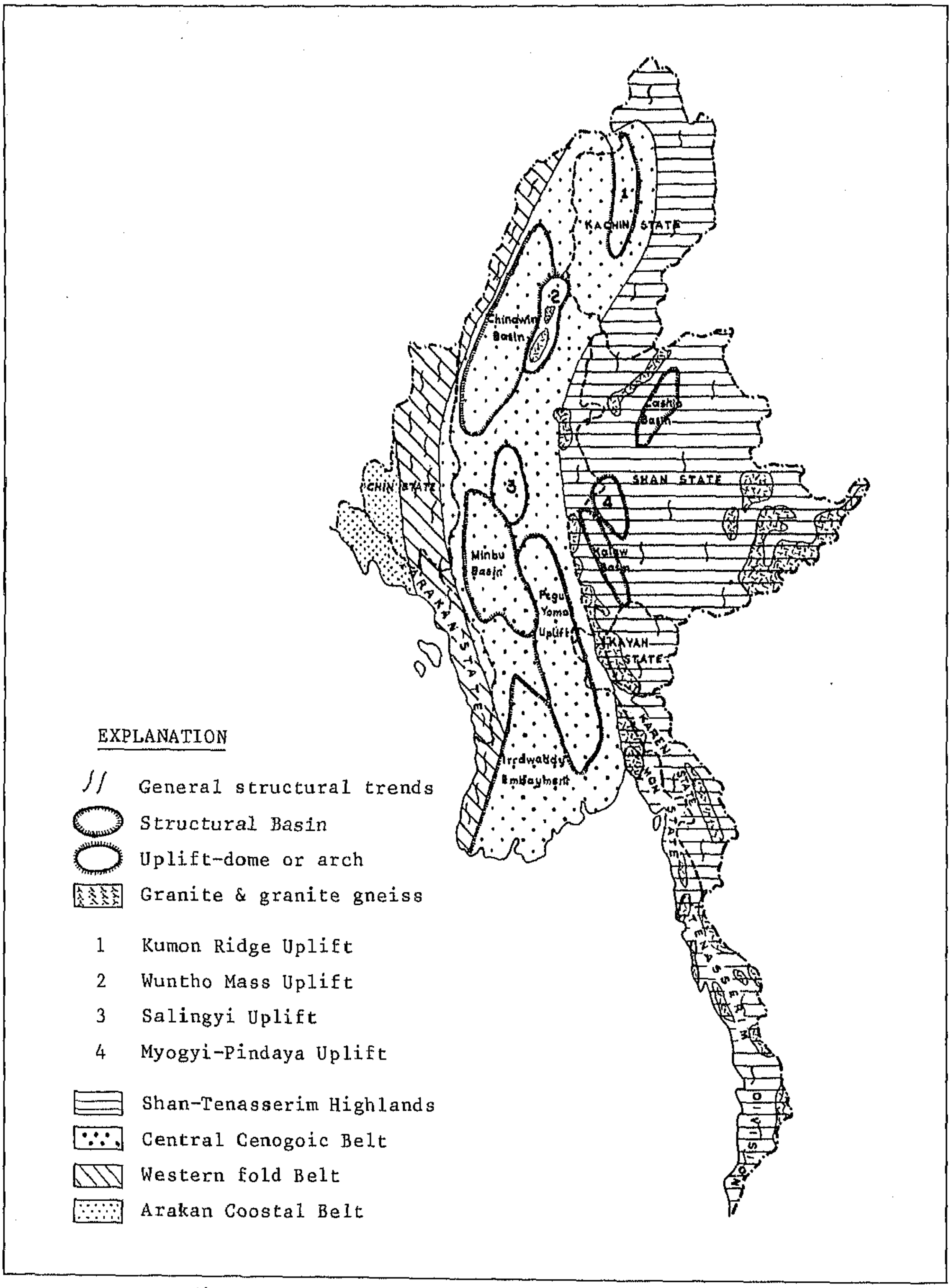


Fig. 2.2.2.1 Generalized Tectonic Map of Burma

2.3. Water Supply Works

2.3.1 Water Supply Administration

In regard to the water supply works, the Burmese Government will, in principle, carry out the installation of facilities and the responsibility for maintenance supervision will be that of the authorities utilizing the water supply. Also, the administrative work is to be borne by 3 Departments; That is to say construction and surveys in connection with city water supply works for the country as a whole are to be undertaken by the General Affairs Department of the Ministry of Home & Religious Affairs; water supplies other than in urban areas such as village water supplies (Rural Water Supply) are to be part of the agricultural department work to be carried out by the Agricultural Mechanization Department of the Ministry of Agriculture & Forests; and facilities connected with Governmental and Public Authorities, are to be constructed by the respective body or done with the help of the Ministry of Construction.

2.3.2 Water Supply and Hygiene

In the 9 towns which were the object of study in the present survey, the incidence of sickness from contagious diseases (reported cases per 100,000 people) is as given in table 2.4.2.1. The prevalent contagious diseases for 1981, '82, and '83 are shown under three main headings, and have been added as data for comparative reference with world statistics. Diarrhoea, as a sickness common to various countries within the tropical belt, has an incidence of several hundred per 100,000 head, however, in Yamethin, Pyawbwe, Yenangyaung and Taungdwingyi this figure is well over the 1,000 mark. (In Taungdwingyi for 1981 and '82, the incidence was much higher).

The incidence of dysentery if in single figures is thought to be good, however in Yamethin, Pyawbwe, Yenangyaung and Taungwingyi the figure was over 400, whereas for India it was 972, and for Thailand only 66 in 1972.

In regard to typhoid and paratyhoid, the 1979 figures for India, Pakistan and Thailand were all around 20 - 40 mark and for rural areas in the Philippines the maximum level of contagion was between 80 - 120. Of the 9 towns under discussion, Taungdwingyi was 78, Shwebo 42, Yenagyaung 41, Pakokku 30, and Pyawbwe 25. Figures for viral hepatitis were, for Yamethin 170, Shwebo 169, Pyawbwe 162 and for Monywa 153, which are fairly high. For the other towns the figure was less than 100.

As far as can be seen from the indicated incidences of contagion for the various diseases, Thazi and Pyinmana have low two-figure rates, which then go on to those of Pakokku, Shwebo and Monywa. The middle range figures for these 3 towns for diarrhoea, dysentery and viral hepatitis were well in the hundreds and as such the need for improvements in hygiene cannot be stressed too much.

Table 2.3.2.1 Cases (deaths) by Water-Borne Diseases (1981 - 1983)

	Item / Township	Population ('83)	Diarrhoea	*	Dysentery	*	Thyphoid & Parathyphoid	*	Viral Hepatitis	*	Food Poisoning	*
Project Townships	Pynmana	221,638	- 483(2) 327(3)	147.5	- 148(0) 106(1)	47.8	- 30(0) 20(0)	9.0	- 130(3) 178(3)	80.3	- 31(0) 30(4)	13.5
	Yamethin	182,096	625(0) 159(0) 3007(0)	1651.3	299(0) 829(0) 942(0)	517.3	7(0) 20(1) 20(0)	11.0	28(0) 136(0) 310(1)	170.2	10(0) 48(0) 79(0)	43.4
	Pyawbwe	206,134	2302(4) 3007(0) 3193(7)	1549.0	888(0) 1050(0) 1258(0)	610.3	110(0) 102(0) 53(0)	25.7	47(0) 279(1) 334(4)	162.0	40(1) 78(2) 26(0)	12.6
	Thazi	147,845	2112(0) 1556(1) 84(1)	56.8	1190(0) 1088(0) 40(0)	27.1	29(0) 115(5) 9(2)	6.1	60(0) 115(0) 18(0)	12.2	25(0) 67(0) -	46.0
	Shwebo	206,344	999(4) 1337(3) 897(3)	434.7	399(0) 507(0) 298(1)	144.4	119(1) 67(4) 87(0)	42.2	89(4) 221(3) 348(7)	168.7	29(0) 38(0) 37(0)	17.9
	Monyma	241,667	- 678(6) 1827(6)	740.6	- 205(1) 493(0)	204.0	- 90(0) 38(0)	15.7	- 196(2) 370(4)	153.1	- 64(1) 89(2)	36.8
	Pakokku	256,680	1062(1) 837(0) 821(2)	319.9	653(0) 788(0) 582(0)	226.7	31(0) 22(0) 79(1)	30.8	70(0) 134(1) 194(3)	75.6	3(0) 15(0) 29(1)	4.9
	Yenangyaung	150,224	781(0) 1732(3) 2470(2)	1644.2	588(0) 1820(0) 697(0)	464.0	36(0) 83(0) 62(0)	41.3	3(0) 51(0) 63(0)	41.9	84(0) 58(0) 20(0)	13.3
	Taungdwingyi	192,239	3045(0) 3198(0) 1864(0)	969.6	1326(0) 1144(0) 1719(0)	894.2	64(0) 121(0) 150(1)	78.0	51(0) 55(0) 176(0)	91.6	26(0) 41(0) 72(0)	37.5
Asian Countries	Philippines		('76)	1000 ~ 3000		200 ~ 300		80 ~ 120		about 200		about 200
	India		('79)	972.3		40.9		-		-		-
	Thailand		('79)	66.2		22.0		-		-		-
	Pakistan			-		-		43.2		-		-

note) up : '81
middle: '82
down : '83

* Morbidity Rate Number of Patients par 100,000 persons.

2.3.3 Present Water Supply Situation

Of the 9 towns included in this study, 4 of them, Yamethin, Monywa, Yenangyaung and Taungdwingyi have some kind of water supply system. As these facilities are of pre-war construction they are becoming rather dated; there are also signs of damage from the war, fires and earthquakes and as such are not really functioning as well as they should. Also, generally speaking, the facilities are small in size and so there is a limit to their distribution area.

Furthermore, as the quantity of water supplied is fairly small, it is not unusual for the supply to be restricted to certain days or even hours within the day.

In the areas supplied with water, communal faucets and concrete water tanks have been set up in various places and most people gather to draw their water in turn from these by means of buckets and water jars which they then carry home.

In areaas that have no such water distribution pipelines and cities that have no water supply facilties, etc., water is derived from sources such as deep wells and open dug artesian type wells.
The deep wells have been fitted with bore hole pumps (mostly Mono-pumps) and air lift pumps fitted with compressors and there are concrete water tanks and water towers of steel plated construction to store the water.
The artesian type wells have been supplied with draw ropes and buckets and other vessels for drawing up the water.
With the existing water supply facilties a lot of people come into direct contact with the water with their hands and so water contamination cannot really be avoided. With WHO - UNICEF and other foreign assited works concerning Rural Water Supply, the water tanks are comparatively hygienic as the number of water tanks fitted with water cocks and covers is quite large.

2.3.4 Water Supply Works with Foreign Aid

A large number of schemes and works undertaken in Burma are assisted and supported by the United Nations, the World Bank, Asian Development Bank and loans from numerous other countries. For instance, through JICA a welfare project involving a 220 bed General Hospital has been realized. As have various projects related to agriculture through OECF, irrigation schemes through ADB loans and EEC grants, and fishery projects with the help of ADB. In addition, the lumber industry has had its machinery brought up to date with help through JICA and there has been additional assistance from other countries as diverse as Australia, Germany, France, Holland and Czechoslovakia. If these projects are looked at for recent projects related to town, rural (agricultural and village) water supplies, the following facts emerge:-

① In 1981 an ADB loan (of $124,000 approved on 3rd July 1981) was used in connection with works of the Agricultural Mechanization Department for a rural water supply scheme involving irrigation works with pumps and land development.

② Also in 1981, a grant was given by the Japanese Government for materials and equipment for the towns of Magwe and Prome.

③ In 1982 an ADB loan (of $15,000,000) was approved on the 15th of October 1982 in connection with water supply works in Mandalay

④ In 1983 OPEC fixed and approved as a supplementary loan the sum of $7,000,000 (19th January 1983) for the above mentioned works in Mandalay.

⑤ In the same year, $914,000 was set aside and approved on the 4th of February for a water supply system forming a link in the Mudon tank irrigation scheme, as a World Bank (IDA) Project. (making a total of $7,914,000)

CHAPTER 3

STANDARDS, GUIDELINES AND OUTLINE OF THE BASIC STUDY

3.1. Design Standards

In regard to design standards in Burma, there are those of WHO amongst others such as BS. With regard to the planning of this project, it was thought necessary to take into consideration the particular features and conditions of the respective towns and so after consultation with Burma's technical staffs the following standards were arrived at: and it is on these that the design of project has been based.

3.1.1 Target Year

The target year for the project is to be 1990, the final year of works in regard to the IDWSSD.

3.1.2 Design Population

The population to be served by the water supply has been determined by calculating the average growth rate figure for each town from the demographic data of the last 10 years. Based on this and the following equation, the target year population for the design of the water supply system was estimated thus:-

$Yx = Yo\ (1 + r)^x$ where

- Yx: is the population after x years from a given year (In this case 1983)
- Yo: is the present population
- x: is the number of years from now to the target year
- r: is the average growth rate

3.1.3 Planned Water Supply Area

Other than urban areas, the design for the proposed towns includes within it land for agricultural use, public land and land for military use, as well as areas where drinking water supplies are unnecessary and areas where independent water supply facilities are being retained.
Accordingly, with this project, land utilization, town planning schemes and needs in regard to drinking water supplies have been examined and water supply areas for each town have been subsequently fixed.
Land uses and classified areas not included in the water supply design are:-

* land for agriculture use and pasture
* land for military use
* land for religious uses
* land for railway stations
* land for government use including public buildings
* land for schools and sports grounds
* land for hospitals
* land for cemeteries
* land for the new extension areas

3.1.4 Water Demand Design Factors

The water demand per person per day is the unit by which the planned capacity is estimated and this has to be determined in regard to the size of the town, climatic conditions and the extent to which it is possible to utilize available water sources. The towns that are the subject of this project all have there own individual features, however, they lie within Burma's dry zone and so, more or less the same conditions apply to each and for this reason the same design standard has basically been taken for all the towns.

Based on the 1981 edition of Small Community Water Supplies by IRC (International Reference Centre), standard domestic water consumption rates are shown in table 3.1.4.

Table 3.1.4.1 Typical Domestic Water Usage

Type of Water Supply	Typical Water Consumption (ℓpcd)	Range (ℓpcd)
Communal water point		
(e.g. village well, public standpost)		
- at considerable distance(>1000m)	7	5 - 10
- at medium distance(500-1000m)	12	12 - 15
Village well walking distance<250m	20	15 - 25
Communal stand pipe walking distance<250m	30	20 - 50
Yard Connection(tap placed in house-yard)	40	20 - 80
House Connection		
- single tap	50	30 - 60
- multiple tap	150	70 -250

Setting the ratio of Communal Stand Pipes to House Connections at 40 : 60 and taking the average figure for single and multiple faucets in house connections, then the quantity of water per person per day (q_1) is given by $q_1 = (50 + 150)1/2 \times 0.6 + 30 \times 0.4 = 72$ litres.

However after discussions with GAD a figure of 15 gals (70 litres) per person per day was agreed on.

A loading factor for determining the maximum water demand per person per day is usually taken as 1.5 from past experience in Japan where the daily water demand per day is some 6,000 cubic meters on average. Thus, the water demand desing calculation for the maximum water demand per day is as follows:-

① Planned daily average supply per capita: q_1

q_1 = 15 gals (70 litres)/capita/day

② Planned daily maximum supply per capita: q_2

q_2 = q x loading factor (1.5)

= 15 x 1.5

= 22.5 gal (105 litres)/capita/day

③ Planned average supply per day: q_3

q_3 = q x planned design population

④ Planned maximum supply per day: q_4

q_4 = q x planned design population

3.1.5 Distribution Capacity

The designed water demand is taken for all intents and purposes as a maximum timewise of the maximum demand per day.

Further, in regard to water for fire fighting, concrete reservoirs for fire fighting purposes have been allowed for in each of the towns and such fire hyrants will not included.

Accordingly therefore the quantity of water required for distribution Q is:- $Q = K \times q_4/24$ where:

K: is the time coefficient (1.5)

q_4: maximum water demand design factor

3.2. Water Sources

3.2.1 Kinds and Points of Water Sources

The raw water for drinking water supply is classified largely into surface water and groundwater. In the case of surface water, river, lake or pond wter shall be used for supply; it is necessary to have a water treatment plant to purify raw water usually, and the construction and operation costs seem to become quite expensive, and it takes a long time impelement from planning to complete construction. In addition to these conditions, to avoid more complicated conditions, the standard water sources in the project shall be groundwater normally, just like the policy of WHO all over the world.

The point of water source and its intake shall be decided in consideration with all information taken from surface and subsurface hydrogeological surveys, records of existing wells such as well logs, results of geoelectric prospecting survey in each town, in the basic design in the field. The well sites have been decided in the area where the groundwater could be available on the basis of technical study results, at the same time, the sites were selected in the area nearer to the water supply areas in each town from the economic point of view.

3.2.2 Groundwater Storage and Water Quality

1) Groundwater Storage

The method of how to estimate the volume of groundwater recharge storage varies depending on whether the groundwater is free or or confined statge, because water balance conditions are variably affected by what state the groundwater is at. As it is extremely difficult to establish water balance conditions for the confined groundwater, estimation of the volume of groundwater recharge storage will be based on water balance conditions for the free groundwater. The volume of groundwater recharge storage is normally estimated through the following two methods;

a. Hydrologically or

b. By knowing volumes, porosities, specific capacities of aquifers.

In the hydrological method, assume a certain area of water balance as well as a constant period for water balance, the following equation can be established;

$$P = D + E + G + M \longrightarrow G = P - (D + E + M)$$

where P = precipitation

D = discharge

E = evaportranspiration

G = groundwater recharge

M = moisture content

Assume a year for the period, the moisture content (M), which does not vary, will be neglected. On the other hand, assume the area as semi-arid, the discharge (D) will also be neglected. Hence, the groundwater recharge (G) can be expressed by:

$$G = P - E$$

As to the precipitation, the data recorded in individual cities will be used. As to the potential evapotranspiration, however, the dta are not always available in all the cities, and so any available data of a city will be used as data for other cities where the data are not available if the temperatures of the cities are more or less similar.

Throughout the year, potential evapotranspiration is more than precipitation, far more during dry season not to speak of. As it is considered the groundwater storage is semi-arid areas is recharged mostly during rainy seasons, the precipitation and evapotranspiration during the rainy season (6 months duration of time from May to October) will be discussed in the following;

As the relationship between the potential evapotranspiration, E and the meters evapotranspiration, Ep is normally given by E/Ep = 0.7, 0.7 will be assumed for E/Ep for all the cities. The groundwater storage recharge, G in milimeter can be expressed by:

$$G = P - Ep \times 0.7$$

and the total groundwater storage recharge in water balance areas will be given by:

$$\Sigma G = G \times A = (P - Ep \times 0.7) \times A$$

where A = groundwater storage recharge area (m^2)

In case of estimating the volume of groundwater recharge storage using the volume and porosity of aquifer, the following equation will be used;

$$V = A \times S \times E$$

where V = volume of groundwater recharge storage (m^3)

A = area (m^2)

S = thickness of aquifer (m)

E = effective porosity (%)*

* The porosity of the Irrawaddy formation is generally 15 to 20%. Taking into consideration the probable differences in the aquifer development and formation at every area, the effective porosity will be assumed 15% for the areas in question and 10% for other areas.

2) Determination of Coefficient of Permeability:

Estimation of the permeability coefficient for soil strata is based on permeability tests conducted on drilled holes or pumping tests on wells. Though there are numerous wells existing in every of the cities, it is rarely known that pumping tests have been conducted in the past. Hence, as a means to determine the permeability coefficient, such factors as static and running water levels and pumping quantities obtained from the wells will be applied.

For a convenient method to estimate the coefficient of permeability based on the aforementioned factors, the equation of Thiem can be raised which is normally used for the purpose, as follows;

Equation of Thiem;

a. Case of Free Groundwater;

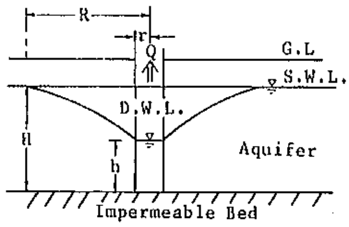
$$k = \frac{2.3Q\log R/\gamma_0}{\pi(H^2-h^2)}$$

where k = coefficient of permeability (m/sec)

R = influence basin (m)

r = radius of well (m)

Q = pumping quantity (m^3/sec)



b. Case of Confined Groundwater;

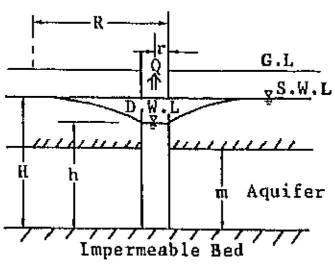
$$k = \frac{2.3Q\log R/\gamma_0}{2\pi m(H-h)}$$

where m = thickness of aquifer (m)

H = distance between aquifers and static water levels (m)

h = distance between aquifers and running water levels (m)

In this estimation, the influence basin is assumed 500 m



3) Estimation of Pumping Quantity:

The pumping quantity in production wells is normally estimated based on stage by stage pumping tests.

As no pumping test is conducted at present, however, it will be calculatively estimated using the known factors.

For the calculative estimation, the equation of Thiem will be used. In order to know the unkonwn water level fall, on the other hand, the equation of Sichardt will be used, as follows;

$$R = 3{,}000\ S\sqrt{k} \qquad S = \frac{R}{3{,}000\sqrt{k}}$$

where R = influence basin (m)

S = water level fall (m)

k = coefficient of permeability (m/sec)

The influence basin, R must be not less than half the distance between adjoining wells to avoid mutual interferences.

Accordingly, the pumping quantity, Q can be expressed by the following equations:

a. Free Ground water: $$Q = \frac{\pi k\{H^2 - (H - \frac{R}{3{,}000\sqrt{k}})^2\}}{2.3\log R/\gamma} \quad (m^3/sec)$$

b. Confined Groundwater: $$Q = \frac{2\pi Dk \cdot \frac{R}{3{,}000\sqrt{k}}}{2.3\log R/\gamma} \quad (m^3/sec)$$

Where the symbols have the same meaning as those previously described.

4) Water Quality

Criteria of water quality is according to the guidelines for drinking water quality by I.R.C.

Guidelines for drinking water quality

Water Quality Parameter	measured as	highest desirable level	maximum permissible level
Total dissolved solids*	mg/l	500	2000
Turbidity	FTU	5	25
Colour	mg Pt/l	5	50
Iron	mg Fe^{+}/l	0.1	1.0
Manganese	mg Mn^{++}/l	0.05	0.5
Nitrate	mg NO_3^{-}/l	50	100
Nitrate	mg N/l	1	2
Sulphate	mg SO_4^{--}/l	200	400
Fluoride	mg F^{-}/l	1.0	2.0
Sodium	mg Na^{+}/l	120	400

3.3. Intake Facility

3.3.1 Production Well, Exploration Well, Observation Well

The lengths, diameters and discharges of production wells should be decided based on conditions of groundwater in each town. The sizes and discharges of production wells described hereinafter have been decided according to only the information of the existing production wells and the results obtained by the electrical resistivity explorations executed this time, but not done by actual pumping tests in exploration wells. It is preferable to make exploration and observation wells in advance of construction of production wells to collect data for designing production wells. The construction methods of production, exploration and observation wells are as follows:-

1) Production Well

8 cities included in this project can be grouped into two by a scheduled quantity of water to be produced; 200 to 700 m^3 per 18 hrs. and 1,200 to 1,400 m^3 per 18 hrs.

These cities are further subdivided because the diameters and lengths of well screens are determined in relation of the required volume of water and the effective quantity of flowing-in water due to movements of sands.

In Pyinmana and Pyawbwe, the discharge per well is 200 to 600 m^3/18 hrs. In such a discharge the diameter of a well is enough in 150 mm (6"). In Yamethin, Thazi, Shwebo and Taungdwingyi, the discharge per well is 500 to 700 m^3/18 hrs. In this case the well diameter is enough in 200 mm (8"). The discharge per well in Monywa and Pakokku is 1,200 to 1,400 m^3/18 hrs. This is relatively a large volume so that a big submerged pump is required as to produce such a volume. The well of 200 mm (8") diameter is recommended in Pakokku, however, upto a depth of 40 m the casing of 250 mm (10") diameter should be used to accommodate a submerged pump inside. In Monywa a well diameter should be all 250 mm (10"). Materials of casings and well screens for production wells should be of a high quality because the life of wells is directly affected by quality of the materials. Especially the well screens should be of stainless steel and the slit size 0.5 mm in width usually used for fine sands. The casings and the screen should be connected in a flush joint to prevent packing gravels from clogging at the joints.

The locations of the proposed production wells should be selected in accordance with results obtained by the electrical resistivity explorations, taking the distribution of the existing production wells into account.

These locations may be changed depending on the results obtained by the exploration wells.

The volume of groundwater to be lifted must be determined within the degree where moving sands in a water-bearing layer do not destroy the layer and do not clog the well screen. Therefore, the diameter and length of the well screen have to be decided on basis of the maximum velocity of sand flowing and the inflow which have been determined from the porosity of the layer and the mean particle size of sands. The procedures of deciding the diameter and length of the well screen are as follows.

a. Determine the hourly discharge of every well.

b. Determine the maximum velocity of sand flowing from the mean particle size of sands. The maximum velocity of sand flowing can be determined using the following Kurihara's formula. (The maximum velocity of sand flowing shall be regarded as equals to that of sand movements.)

   In case of $d < 0.085$ mm, $V_c^2 = (-76.0 \log 1.18d - 37.2)d$

   $d = 0.085$ to 0.213 mm, $V_c^2 = (16.21 \log 1.18d + 55.0)d$

   $d > 0.213$ mm, $V_c^2 = (83.71 \log 1.18d + 92.3)d$

   where d = Mean Particle Size in cm.

c. Determine the inflow volume and the effective inflow volume of every well. In this stage, the diameter of every well is decided.

d. The hourly discharge multiplied by the effective inflow volume becomes the length of the well screen. If the screen is greater than the thickness of the water-bearing layer, the well diameter and length of the screen must be adjusted properly.

   The water-bearing layer's porosity n and the mean particle size d by each town shall be:

   (1) $n = 0.3$, $d = 0.05$ cm for Pyawbwe and Thazi

   (2) $n = 0.3$, $d = 0.10$ cm for Pyinmana, Yamethin, Shwebo and Taungdwingyi

   (3) $n = 0.3$, $d = 0.20$ cm for Monywa and Pakokku

2) Exploration Well

The purpose of the exploration well is to collect data concerning the depths of the water-bearing layers and the conditions of groundwater storage (coefficients of aquifer, optimum discharge, etc.) under the proposed well sites and all over the vicinity in advance of construction of the production wells. The number of the exploration wells is desired more than 50% of the production wells. The exploration well shall be 10 m apart from the production well and so distributed as to form a triangular shape in order to know the strike, dip and depth of the water-bearing layer and collect other miscellaneous data. The borehole diameter for the exploration wells shall be 9-5/8" and the casing and screen diameters 150 mm (6"). The screen shall have the horizontal slits of 1 mm in width and the open area of 5 to 5.5% and be installed at the depth of the major water-bearing layer. The length of the exploration well shall be longer by 50 m than that of the production well.

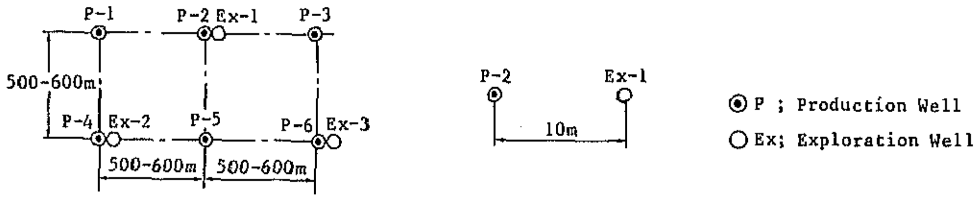


Fig. 3.3.1.1 *Layout of Exploration Well*

After roles of the exploration wells, they are used as the observation wells during pumping tests in the production wells and for monitoring fluctuations of the groundwater levels in a long term.

3) Observation Well

The observation wells are installed for the purpose of studying the interferences between the production wells, the influences on the groundwater caused by the production wells and the tendency of changes in a well yield in a dry and rainy season throughout the year. The obtained data is useful for maintenance and control of the production wells.

The observation wells are classified into two types according to their uses; one is a secular type well to observe fluctuations and/or conditions of groundwater all over the area and another is one to observe the interferences between the production wells. Each one observation well shall be installed in the upstream, the midstream and the downstream of the groundwater stream respectively within the production well sites. The fluctuations of groundwater shall be recorded with a 45-day term automatic water-gauge set at every secular observation well. Interferences between the production wells shall be also observed every one month with a simplified water-gauge set at the observation well installed at the center or by the side of the group of several production wells. The borehole for the observation well shall be drilled down in a diameter of 7-5/8" and the casing and screen shal be 100 mm (4") in diameter.

The depth of the observation well shall be the same as that of the production well. The screen shall have a horizontal slit of 1 mm in width and an open area of 5 to 5.5%. Taking into account that the observation wells are more important than the production wells because the obseration wells serve the investigation of yields and balance of groundwater in the production wells and/or all over the area, FRP pipes resistant to abrasion, corrosion and electrolytic corrosion are desired to use.

3.3.2 Pumps and Electrical Power

1) Pumps

For submersible pumps are to be used for raising the ground water, however no pumps will be provided for pumping the water from the wells to the water towers in the distribution areas as the delivery head of the submersible pumps is to be higher than that of the reservoirs and water towers but such as to avoid damaging the water supply pipes and pump facilities. Also the operating time for the pumps per day has been fixed at 18 hrs.

i) Specifications in regard to Submersible Pump

The power and diameters of inlets and outlets of the pump can be ascertained from the designed discharge and pump head requirements. The planned discharge capacity is determined by the following equation:-

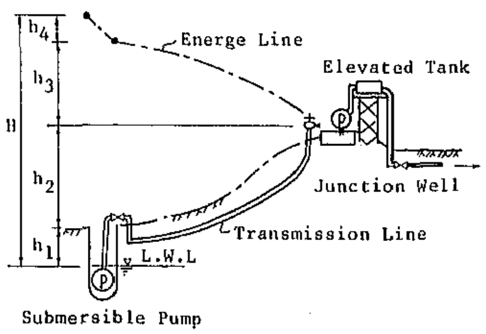
$Q_1 = Q_2 T$, where

Q_1: is the pump discharge capacity in m^3/min.

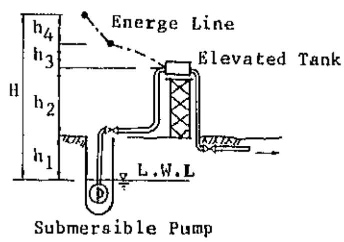
Q_2: is water requirement from the well in m^3/day

T: is the operational period of the pump (18 x 60 = 1,080 min)

Also, the planned head of the pump can be determined from the type of water distribution system adopted in this project as follows:-



- Type 1 -



- Type 2 -

H : is the planned head in m ($h_1 + h_2 + h_3 + h_4$)

h_1: height between the ground level of the well and the dynamic water level in m

h_2: height difference between the well and storage facilities in m

h_3: loss of head through friction in pipes in m (ref. distribution facilities)

h_4: Miscellaneous losses from pipe work around the pump.

ii) *Inlet and Outlet pipe sizes*

The outlet sizes of the pump are determined the velocity and capacity of the pump by the following equation:-

$D = 146\sqrt{Q/V}$, where

D: is the outlet diameter

Q: is the discharge rate in m/sec

V: is the velocity of water at the outlet in m/sec (i.e. 1.5 - 3 m/sec)

iii) Shaft Power

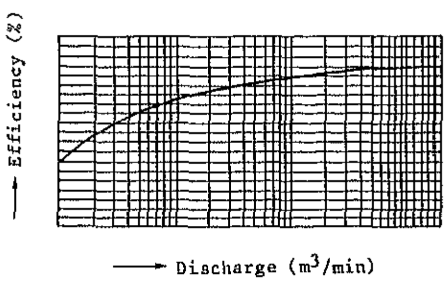
The shaft power is determined from the discharge capacity and planned head of water and pump efficiency by the following equation:-

$L = 0.163Q \times H/n$, where

L: is the shaft power in Kw

Q: is the discharge capacity in m^3/min

n: is the efficiency of the pump



Standard Efficiency of Pump

Source: The Water Works Standard of Japan

2) Electric Power Supplies

Of the nine towns in question, sufficient supplies of electricity are available in Thazi, Monywa, Pakokku and Yenangyaung. In Shwebo and Taungdwingyi electricity is dependent on generators; and in Pyawbwe, Yamethin and Pyinmana it is supplied by the hydro-electric power station at Law pita. However these supplies are inadequate for the projects needs. At the moment however, a project financed with a West German loan for the erection of transmission lines from Thazi to Toungoo and an electricity supply project for Taungdwingyi to be financed with a Japanese grant in confunction with a separate project to supply Shwebo all scheduled to be completed within 2 years mean that sufficient electricity should be available for the operation of the planned wells for the towns sometime in the near future.

Electric Power Supplies in Burma are the responsibility of the Electric Power Corporation (EPC). However, EPC cannot be called upon to furnish materials and equipment in regard to this project, so they have all been accounted for within the present design.

In regard to the supplying of electricity for the new wells, power lines will be run from the most conveniently available transformer station to the well. In the event that the wells are some distance away, a transformer station will be built within the centre of several wells and then lines run to each well. Except for Pyinmana the primary voltage is to be 11KV and the secondary voltage 400V at a frequency of 50 Hz.

3.4. Water Supply Facilities

3.4.1 Utilization of Existing Facilities

4 of the 9 towns under review, Yamethin, Monywa, Yenangyaung and Taungdwingyi have existing water supply systems, and the other towns have many deep and shallow wells. It was one of the objects of the present investigation to try and maximize the utilization of these within the new scheme, however, nearly all the existing facilities are of old construction and have become obsolate and except for those of Yamethin and Yenangyaung they cannot be readily utilized.

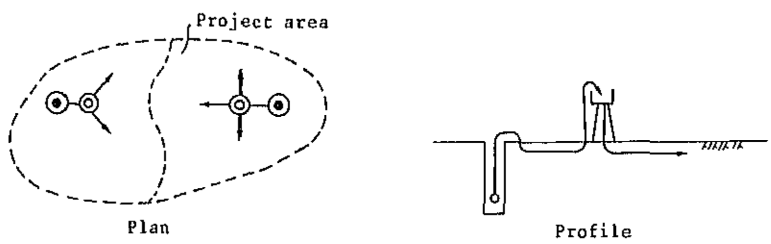
This is especially so in regard to existing wells where the number of wells that can be relied on throughout the year is low.

In addition they do not meet WHO standards and even if they did meet both the aforementioned requirements the possibility of them providing the quantities of water necessary is slight. For these reasons they have not as a matter of principle been incorporated in the present design.

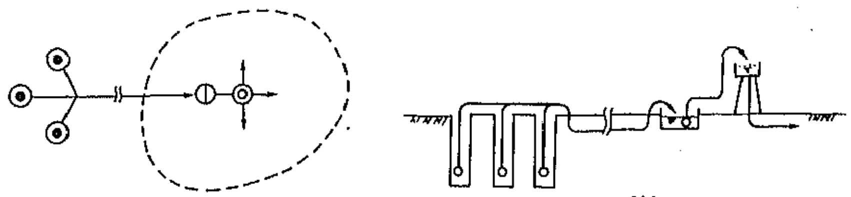
3.4.2 Drinking Water Supply System Design

Each of the towns within this project have their own respective features in regard to topography, hydrology and morphology of the towns. Accordingly therefore in the desing of drinking water supply systems for each town, an attempt has been made to equate the design with the features of the town and locality. The result of this is the devising of three basic systems that can be utilized either independently or together, as shown below.

System 1. The wellsite can be constructed in the project area.

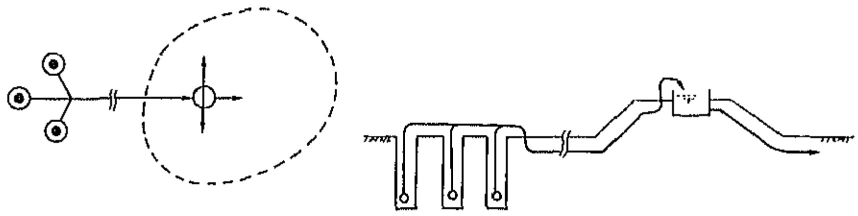


System 2. The wellsite is a from the project area which is almostly flat.



Plan Profile

System 3. There are some hills can be used as the reservoir area, in spite of the wellsite is not only in the project area but also out of the area.



Plan Profile

Legend ◉: Intake well ⊕: Reservoir
◎: Elevated tank ⦶: Junction well

Fig. 3.4.2.1 Basic System of Water Supply

3.4.3 Water Distribution Facilities

Water distribution facilities consist of pipelines connecting production wells and auxiliary facilities. In principle a T form ductile cast iron pipe is to be used, however from the point of view of maintenance a steel is to be used where pipes are to cross railways or rivers.

The diameter of the main distribution pipe from well to town has been selected so that the velocity in the pipe doesn't exceed 1.0m/sec; pipes meeting this size requirement are to be selected on the standards laid down for ductile pipes.

The diameter is determined as follows:-

$D = 4Q/\pi v$, where

D: is the required diameter in m

Q: is the volume of water passing through the pipe in m^3/sec

V: is max flow speed in the pipe in m/sec (less than or equal to 1.0 m/sec)

π: is the ratio of the circumference of a circle to its diameter

In general the flow capacity in the pipe is calculated according to the Hazen-Williams formula, from which the hydraulic gradient and friction loss can be obtained.

$$I = 10.66 \times C^{-1.85} \times D^{-1.87} \times Q^{1.85}, \text{ where}$$

I: is the hydraulic gradient

C: is the flow speed constant (including loss caused by bends, C=110)

D: is the internal diameter of the pipe

Q: is the flow capacity in m/sec

The friction losses in the pipe are determined from the hydraulic gradient and the pipe length, i.e.

$$H = I \times L, \text{ where}$$

H: is the friction loss head in m

L: is the length of pipework in m

3.4.4 Water Distribution Facilities

The water distribution facilities consisting of ground reservoirs or elevated tanks, in which the drinking water sent from the wells is briefly kept, difer greatly from those of the water supply network used to distribute the water within the supply area.

Up to the storage facilities a gravity system is used to distribute the water, i.e. within the supply area ground reservoirs are erected on some suitable high ground and where such vantage points are not available elevated tanks are to be built. Water level control in the reservoirs and tanks is to be done manually by watchmen; and the effective capacity of the ground reservoirs is to be 2 hrs equivalent of the maximum daily requirement and 30 min of the for elevated tanks. Furthermore, in regard to elevated tanks facilities, if the wells are far away and the quantity of water to be stored is large, then the water is to be received by a ground reservoir and then raised up to the elevated tank. In such a case the volume water in the ground reservoir and the elevated tank stay the same as above. The maximum height of the elevated tank is to be about 15M and the structure is to be designed to withstand the effects of wind pressure when empty and earthquakes when full. In principle ductile cast iron pipes are to be used for the distribution pipes and electronic equipment is to be sued for the metering of the flow capacity in the pipe network.

Where the wells are far from the town and failry scattered, then water is to be collected at a junction well (as in the water supply system in 3.3.2).

The booster pump must have sufficient head to ensure that the water can be lifted up to the wter towers and the total capacity must meet planned requirements. The planned discharge and required head for this is calculated as follows:-

i) Designed Water Requirement

$\Sigma Q = n \times Q_1$, where

ΣQ: is the designed water requirement in m^3/min

n: is the no. of wells connected to the junction well

Q_1: planned discharge per well pump in m^3/min

Also, the planned head of water of the pump can be determined from the type of water distribution system adopted in this project as follows:-

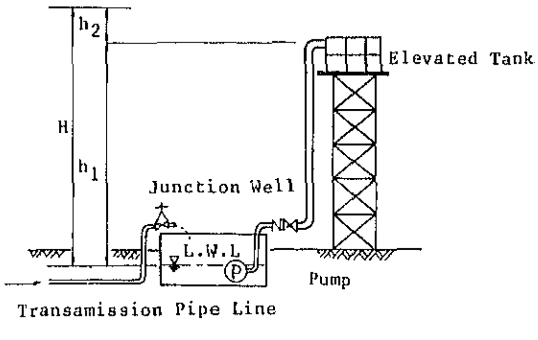
ii) Planned Head of Water

$H = h_1 + h_2$, where

H : is the planned head of water in m.

h_1: is the difference in height between the jucntion well LWL and the water tower HML in m.

h_2: is for losses at the pump



The booster can be either a submersible type or a ground level type, the features of which are given below:-

	Submersible type	ground level type
Operation at high temperatures	Very efficient as the water keeps it cool	Efficiency falls because of temperature rises
Water proofing	No need of grand paking	Possibility of water permeation
Pressure fluctuation	No pressure fluctuation	Possibility of it occurring
Cavitation	Doesn't occur	Possibility of it occurring
Inspection	Good	Often machinery is complicated

Of these two alternatives the submersible pump is by far more expensive, however, it has been chosen as it is better in operation and easier to repair etc.. Furthermore, with submersible pumps construction of covers and foundations are not necessary which is another point in it's favour.

3.4.5 Calculation of the Water Flow in the Pipe Network

The flow capacity calculation based on the Hardy-Cross principle was carried out by convergent analysis with the aid of a computer. The formula used in accordance with the Hardy-Cross principle was the Harzen-Wiliams formula.
An outline of the method of calculation is given below.

i) Pipework for the Distribution Network

The planned water supply areas have been divided in respect of population density and, so that each area can be easily supplied with water, pipework is to be laid along existing roads (or along the path of planned roads in extension areas)
From supply point fixed by the above, suitable water capacities can be determined for the population within each divided area.

ii) Design Flow Inlets

In planning the pipe network, some points where it is possible to utilize the lands morphology, or where it is deemed advantageous for distribution purposes, have to be fixed and taken as flow inlet points. (In actual practice this is at a reservoir or tower). The flow inlet capacity is equal to the total supply volume and has been decided as a premise that the flow inlet point head of water at the end of the distribution pipes should be maintained at 0.4 kg/cm^2 (equal to a head of water of 4.0M)

iii) Calculation Method

In the calculation, the pipelength, velocity coefficient and the flow capacity and pipe diameters for the respective pipes are assumed, but even so, in conjunction with the Harzen-Williams formula, this allows the determination of the flow volume and friction losses. For, until the values for each respective pipe line in the network converge rationally, the resultant volume is repeatedly recalculated.

$$h = rQ^{1.85}$$

$$r = 10.666 \times C^{-1.85} \times D^{-4.87} \times L$$

$$\Delta Q = -\Sigma h / 1.85 \Sigma k, \text{ where}$$

K is h/q

h is the loss in head of water (m)

r is a constant determined from the pipe diameter, pipe length and velocity constant

C is the velocity constant ($\fallingdotseq$ 110)

D is the internal diameter of the pipe (m)

L is the length of the pipe in (M)

ΔQ is the corrected flow volume rate in (m^3/sec)

iv) Calculation Results

The repeated calculated yield and following facts:-

* internal pipe flow volume and velocity
* respective diameter of each pipe
* water pressure at each inlet point

3.5. Outline of Survey

3.5.1 Survey for Groundwater Resource

1) Investigation of Existing Wells

In this investigation, locations, types, depths, diameters and discharges of the existing wells were investigated and measurements of groundwater temperature, electric resistivity and simple examination of groundwater quality, including pH value determination, were performed on obtained water samples. Although a similar investigation had been carried out by a Burmese agency, this investigation was performed by us in order to ascertain as well as supplement some items of investigation. The information concerning the depths and discharges of the wells was obtained through inquiry.
Accordingly, the information may differ from the actual depths and discharges.

2) Electric Resistivity Exploration

In the electric methods of resistivity exploration, there are two methods, that is a spontaneous potential method to measure spontaneous potentials and an artificial potential method to measure electric currents conducted into the ground through current electrodes. For this exploration, the latter method was adopted. This artifical potential method is based on differences in electrical conductivity or resistivity of the surface materials. As shown on Fig. 3.5.1.1, two current electrodes C1 and C2 are placed and an electric current I is flown from C1 to C2.
A potential difference V between two potential electrodes P1 and P2 in a line through two current electrodes C1 and C2 is computed as follows.

$$V = V_{P1} - V_{P2} = \frac{\rho 1}{2\pi}\left(\frac{1}{C1P1} - \frac{1}{P1C2} - \frac{1}{C1P2} + \frac{1}{P2C2}\right)$$

where ρ is an electrical resistivity of the surface materials.

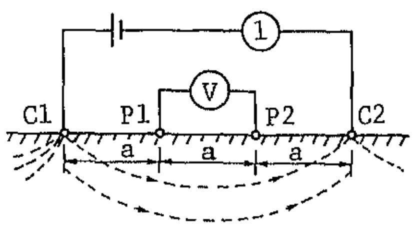


Fig. 3.5.1.1 Electrode Configuration

In case of the current electrodes are placed in C1P1 = P1P2 = P2C2 = a, the potential difference V becomes $(\rho I/2\pi)(1/a)$. Accordingly, the following equation is obtained.

$$\rho = 2\pi a \frac{V}{I}$$

Consequently, the electrical resistivity of the surface materials can be obtained for the above equation.

Resistivity explorations are continuously performed varying the spacing of the electrodes. And the relationship between ρ and a is profiled and by analysing their relationship the geological structure can be presented.

This method of resistivity exploration is called Wenner Method.

In this exploration, the spacings of the electrodes were varied as shown on Table 3.5.1.1. These spacings were so selected that they became nearly the same as them of the wells, however, they were changed depending on the geological conditions. As the depths of the explorations were decided with reference to data in hand concerning the existing wells, they were various in towns. This resistivity exploration was performed to a maximum depth of 200 m taking capability of a measuring device into account.

Table 3.5.1.1 Electrode Intervals

	0 - 1m	1 - 3m	3 - 20m	20 - 40m	40 - 100m	100 - 200m
Electrodo Intervals	0.3m	0.5m	1.0m	2.0m	4.0m	10.0m

3) Groundwater Quality Examination

The examination of groundwater quality was made on samples obtained from the existing wells on site and also in a laboratory. The field examination of groundwater was performed to determine its temperature, electrical conductivity and pH value during the field works. The field results of this examination have been reported in the appendix of the well investigation report. The laboratory examination of groundwater was made on samples taken from a typical well of each town at the National Health Laboratory in Rangoon. This laboratory examination was made as to the following items.

① Appearance
② Total Solids
③ Total Hardness
④ Permanent Hardness
⑤ Calcium Hardness
⑥ Total Iron
⑦ Chloride
⑧ pH

The interrelationship between Total Solid Contents and the electrical conductivity obtained by this examination is indicated on Fig. 3.5.1.2. As obvious from this figure, the intersecting points of Total Solid values and electrical conductivity values range on or near the line of TS = 1/1.5EC. This interrelationship is very similar to that of Osaka-city. The results of the laboratory examination are specified in Chapter 4 by town.

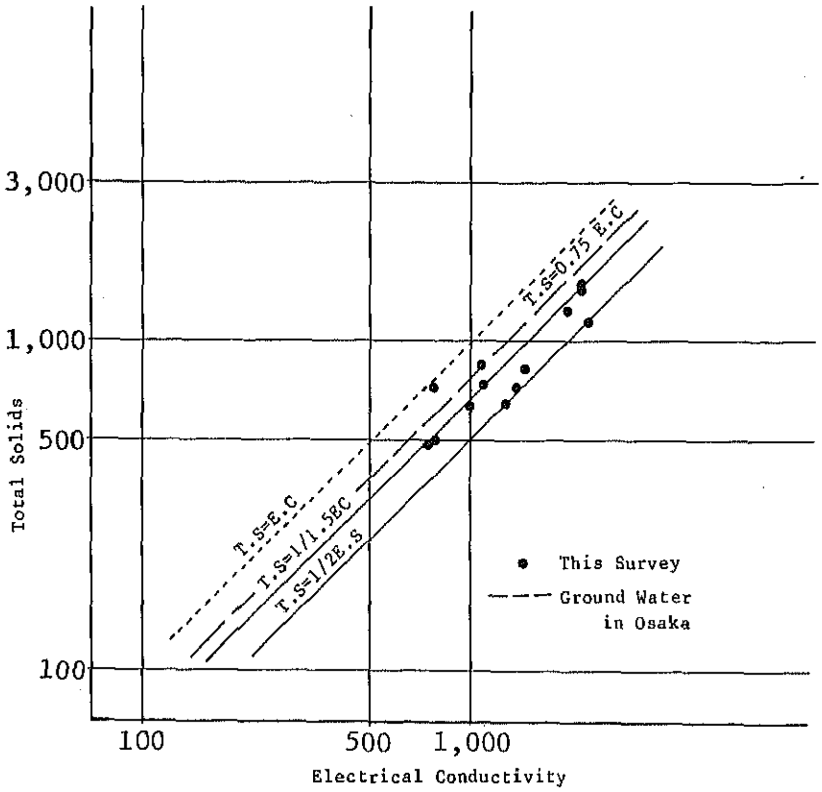


Fig. 3.5.1.2 Relation of E.C and T.S

3.5.2 Water Supply Area Survey

With regard to carying out the water supply and facility planning, besides undertaking a site survey, discussions were held with TDC members in the respective towns to establish a basic policy in connection with the planning of the water supply facilities and as a result some basic proposals were arrived at.

The contents of the survey was as follows:-

① The geography and morphology of the planned area

② The utilization factors in regard to roads, rivers, railways and land.

③ The present distribution of people and industry and future development plans

④ Existing water supply facilities and the condition of supplied water

⑤ Preparation of the basic proposals for the design of the water supply system

⑥ Discussion and explination of the basic proposals with TDC members.

Also in regard to the request for assistance with additional materials and equipment for Prome and Magwe, discussions and an evaluation of the contents of the request in connection with future progress and state of advancement of the construction works was carried out.

CHAPTER 4

DESIGN OF WATER SUPPLY SYSTEM FOR EACH TOWN

The cities surveyed, although different in size from each other, are all important places of railways and roads, and are important bases of the commerce and industry in the respective areas. However, these cities have hardly accomplished consolidating water supply systems enough to cope with the town development, and as they are, they do not know what to do for securing drinking water. Of the project cities, Monywa, Yenangyaung and Taungdwingyi have the existing water supply systems, but all these systems are small-scaled and have extremely insufficient supply capacities to date. Moreover, they are several decades old and badly deterorating, so that few of them can be used further in the future. The other cities have no water supply systems, and in most of them, private wells and public artesian wells are relied on, but in those cities in which even these wells are not available, the surface water of rivers, lakes, etc. is inevitally used directly as drinking water.

In this survey, the construction, water quality and hydrogeology of the existing wells in each city were examined, and also, field-explorations of the project areas including their surroundings were carried out. Further, electric prospecting was conducted as necessary, to grasp the storages of groundwater and the feasibility of well construction for setting the positions of planned wells and determining the well structure and possible intake capacities. Regarding planning the water supply systems, the planned water supply population and planned water supply capacities were investigated from the data of geography, land utilization, population distribution and city development plan, etc. of each city. For those cities which have the existing facilities, studies were made for the purpose of utilizing them for the planned facilities, and facility plans were set up to conform to characteristics of each city.

The outlien of the area, ground water development plan, and planning the water supply system of each city are described on the following pages. For planning the water supply systems, lists have been prepared for the purpose of comparison between cities of the situation, conditions and planning specifications. (Refer to Table 4.1.)

Table 4.1 Summary of Each Town

	Item \ Town	Pyinmana	Yamethin	Pyawbwe	Thazi	Shwebo	Monywa	Pakokku	Yenan-gyaung	Taung-dwingyi
Condition of the Towns	Division	Mandalay	Mandalay	Mandalay	Mandalay	Sagaing	Sagaing	Magwe	Magwe	Magwe
	Distance from Rangoon (km)	320	400	410	450	640	590	520	420	360
	Number of Wards	6	5	8	7	10	18	15	14	10
	Altitude above Sea Level (m)	92 ∼ 122	200	200 ∼ 230	214	92 ∼ 122	75 ∼ 120	53 ∼ 69	75 ∼ 100	83
	Area of Town Proper (km^2)	5.7	7.7	6.4	2.4	6.1	21.9	9.6	33.0	6.6
	Temperature Upper Summer	42 ∼ 15°C	max 42°C	max 35°C	42 ∼ 17°C	max 43°C	42 ∼ 21°C	max 43°C	max 44°C	44 ∼ 37°C
	Temperature Lower Winter	38 ∼ 8°C	min 29°C	min 20°C	31 ∼ 5°C	min 28°C	29 ∼ 12°C	min 10°C	min 27°C	30 ∼ 33°C
	Rain Fall Ave. (mm)	900 ∼ 1,850	609 ∼ 1,063	172 ∼ 1,180	480 ∼ 1,011	460 ∼ 1.138	315 ∼ 1,070	173 ∼ 774	388 ∼ 483	458 ∼ 1,390
Summary of Planning	Existing Population ('83)	51,275	22,598	23,834	18,434	48,920	105,096	70,265	71,475	38,563
	Increasing Rate of Population (%)	1.8	1.4	2.2	1.9	2.1	2.5	2.2	1.6	2.0
	Served Population ('91)	59,200	25,300	28,400	21,400	57,800	128,000	81,800	81,200	45,200
	Total Water Demand (m^3 day)	6,200 (1.24)	2,700 (0.54)	3,000 (0.60)	2,300 (0.46)	6,100 (1.22)	13,500 (2.79)	8,600 (1.72)	8,500 (1.70)	4,800 (0.96)
	Discharge Rate per Well (m^3/day)	600	600	200	500	700	1,400	1,200	1,590	700
	Number of Proposed Wells	10	5	15	5	9	10	7	* 5	7

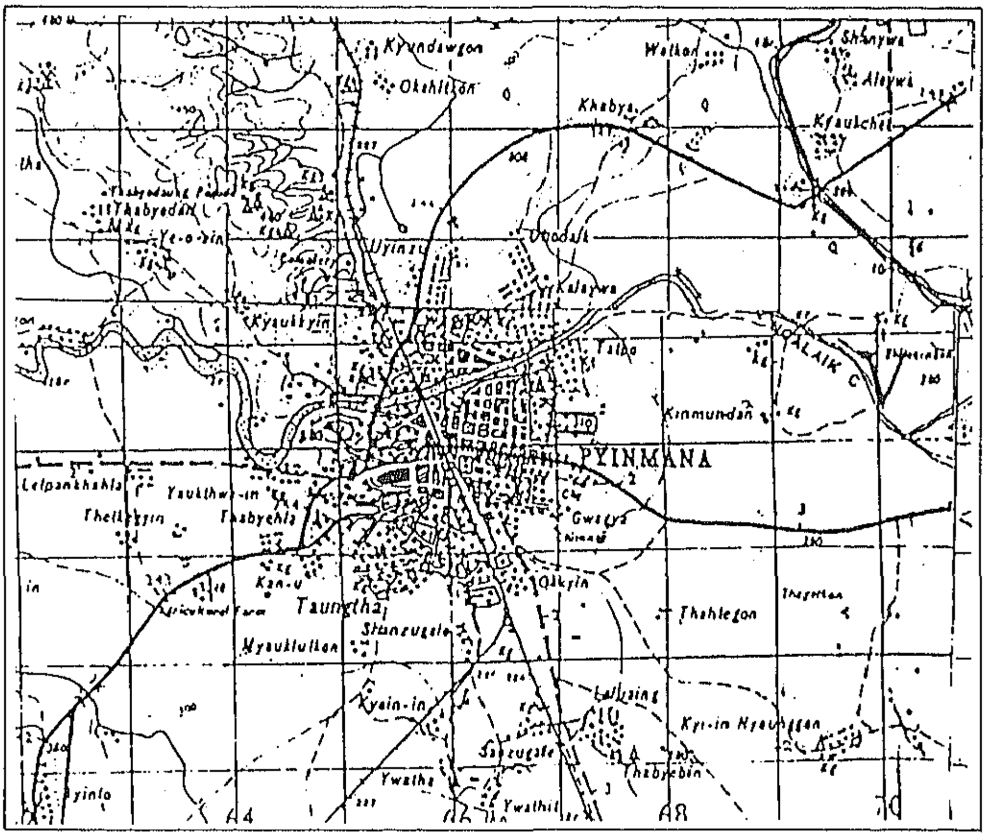
* Infiltration Gallery Well

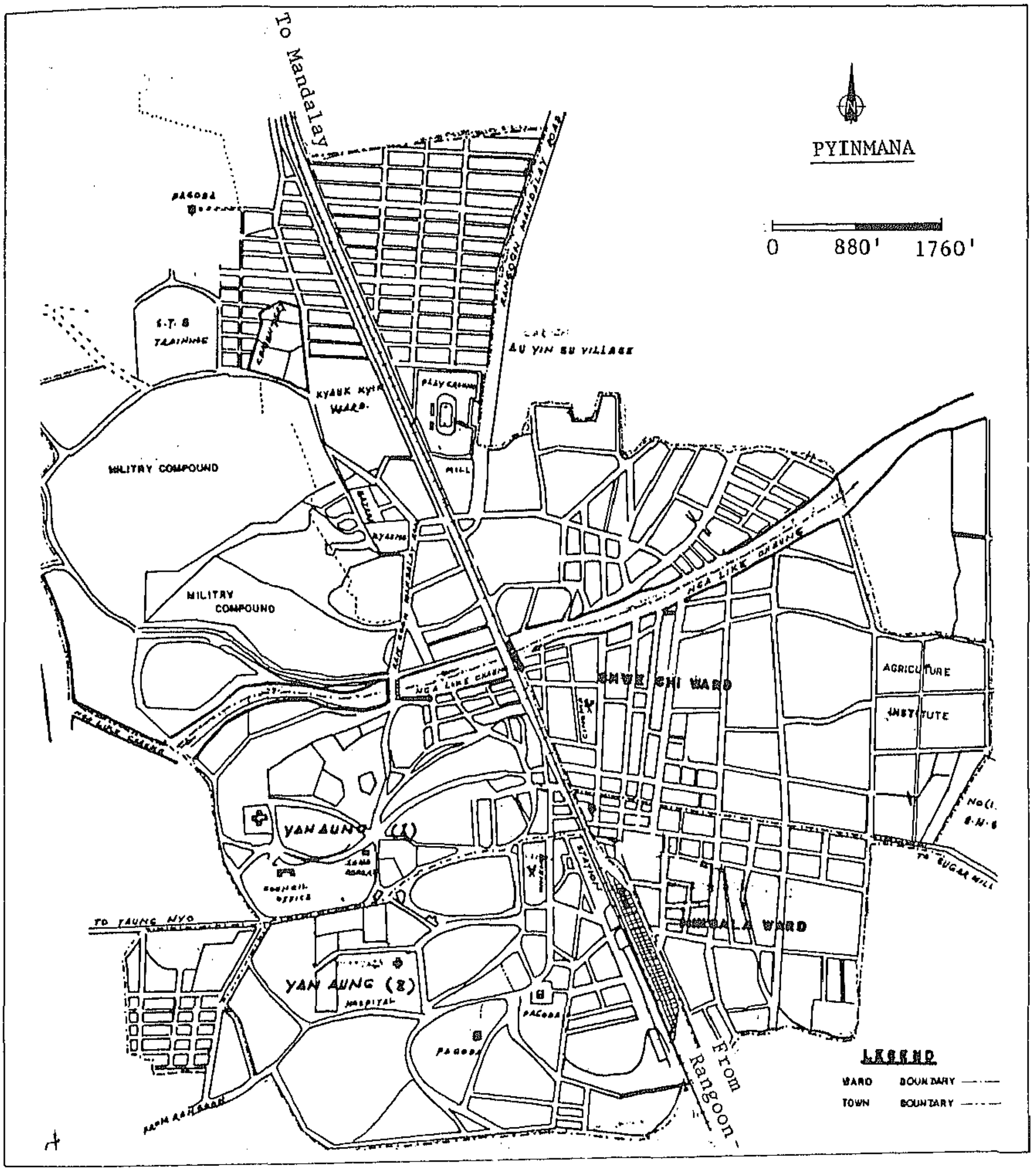
(   ) Million Gallons

Table 4.2 Quantity List of Main Facilities of All Towns

	Item	Pynmana		Yamethin		Pyawbwe		Thazi		Shwebo		Monywa		Pakokku		Yenangyaung		Toungdwingyi		Total	Remarks
Intake Facility	Production Well	Q=600-650 150x76	10	Q=600-650 200x176	4	Q=200-250 150x46	15	Q=500 200x36	5	Q=700 200x206	9	Q=1,400 -1,500 250x56	9	Q=1,200 -1,250 250x160	7	*Q=1,590 3,600x6.0	5	Q=700 200x76	7	5* 66	Discharge Q (m^3/day) Gallery Well Dia (mm) x Depth (m)
	Expro.W.	150x90	5	150x220	2	150x55	8	150x40	2	150x250	5	150x65	5	150x130	4	–	–	150x90	3	34	Dia (mm) x Depth (m)
	Obser.W.	100x76	8	100x176	4	100x46	9	100x36	4	100x206	7	100x56	8	100x106	6	–	–	100x76	6	52	Dia (mm) x Depth (m)
	Intake Pump	100x15 80x11	4 6	80x15	4	50x7.5 50x5.5 50x5.5	1 8 6	65x11	5	80x11	9	125x22 125x18.5 80x3.7	4 5 1	100x30	7	*150x55	3	80x11	7	3* 67	Dia (mm) x Power (km) Suction Pump
	Pump.Room	A=16.0	10	A=16.0	4	A=16.0	15	A=16.0	5	A=16.0	9	A=16.0	9	A=16.0	7	A=167	1	A=16.0	7	67	A (m^2)
Trans. Facility	Trans.Pipe	ϕ150-ϕ200	3,790m	ϕ150-ϕ300	2,800	ϕ75-ϕ200	17,140	ϕ100-ϕ250	3,040	ϕ150-ϕ250	9,540	ϕ200-ϕ300	5,720	ϕ200-ϕ350	3,980	–	–	ϕ150-ϕ350	3,270	49,280m	Dia (mm) Ductile Iron Pipe 3T
	Slui,Valve	ϕ150-ϕ200	6	ϕ150-ϕ300	5	ϕ75-ϕ200	18	ϕ100-ϕ250	5	ϕ150-ϕ250	9	ϕ200-ϕ300	8	ϕ200-ϕ350	8	–	–	ϕ150-ϕ350	6	65	Dia (mm)
	Air Valve	ϕ20	5	ϕ20-ϕ25	4	ϕ20	23	ϕ20-ϕ25	4	ϕ20-ϕ25	13	ϕ20-ϕ25	8	ϕ20-ϕ25	6	–	–	ϕ20-ϕ25	5	68	Dia (mm)
Distribution Facility	Ground Reservoir	V=210	1		–	V=20	1		–		–		–	V=315 V=410	1 1	–	–		–	4	Storage Vol. (m^3) Ground Reser. RC Stru
	Junction Well		–		–	V=100 V=130	1 1	V=190	1	V=170 V=175	2 1	V=480 V=210 V=150 V=140	1 1 1 1		–	–	–		–	10	Storage Vol. (m^3) Ground Reser. RC Stru
	Elevated Tank	38.9x15.0 12.9x15.0	1 3		–	32.6x15.0 25.2x15.0	1 1	46.8x15.0	1	41.3 ∫ x15.0 43.3	3	50.5x15.0 30.8x15.0 34.1x15.0	1 1 2		–	–	–		–	14	Storage Vol. (m^3) FRP, Steel Base
	Distri. Pipe	ϕ75-ϕ200	16,840m		–	ϕ75-ϕ150	13,190	ϕ75-ϕ200	8,720	ϕ75-ϕ200	25,670	ϕ75-ϕ350	45,320	ϕ75-ϕ250	27,440	–	–	ϕ75-ϕ250	20,230	157,410m	Dia (mm) Ductile Iron Pipe 3T
	Slui.Valve	ϕ75-ϕ200	57		–	ϕ75-ϕ150	46	ϕ75-ϕ200	27	ϕ75-ϕ200	60	ϕ75-ϕ350	127	ϕ75-ϕ250	71	–	–	ϕ75-ϕ250	53	441	Dia (mm)
	Air Valve	ϕ20	36		–	ϕ20	28	ϕ20	20	ϕ20	58	ϕ20-ϕ25	95	ϕ20-ϕ25	57	–	–	ϕ20-ϕ25	43	337	Dia (mm)
	Booster Pump		–		–	125x11 100x7.5	1 1	150x15	1	150x11	3	250x30 150x15	1 3		–	–	–	200x22	1	11	Dia (mm) x Power (km)
Electric Power Faci.	Transformer Equip.	100 25	1 1	150	1	75 50	1 1	100	1	150	1	100 50	1 2	100	1		–	100	1	12	3ϕ4W (KVA) 11KV/0.4KV
	Power Cable	14°-100° 8°x4c	27.8km	60° 8°x4c	1.5	14°-80° 5.5°x4c	47.0	50° 8°x4c	9.4	14°-100° 14°x4c	23.4	30°-50° 14°x4c -22°x4c	28.4	22°-60° 22°x4c	17.1		–	22°-80° 8°x4c	18.0	172.6km	OW- CV- (km)

4.1 Pyinmana




PYINMANA
0 880' 1760'
To Mandalay
From Rangoon
MILITRY COMPOUND
MILITRY COMPOUND
SHWE CHI WARD
AGRICULTURE INSTITUTE
YAN AUNG (1)
YAN AUNG (2)
HOSPITAL
PAGODA
TO TAUNG NYO
TO SUGAR MILL
AU YIN SU VILLAGE
KYAUK KYI WARD
MILL
STATION
LEGEND
WARD BOUNDARY
TOWN BOUNTARY

4.1.1 Outline of The Area

Pyinmana is situated in the central part of Burma, 360 km by railways and 390 km by roads from Rangoon. It is located at the southeast end of the arid area in the Union of Burma. It has the largest precipitation among the cities covered by this project, and is a city blessed relatively with water. The average annual precipitation for the past ten years is 1300 mm. The maximum and minimum air temperatures in summer are 42°C and 15°C, respectively, and the maximum and minimum air temperatures in winter are 38°C and 8°C, respectively.

The town area is 5.7 km^2 and the present population is 51275 persons. The annual average population growth rate for the past 10 years is 1.8%.

Pyinmana is surrounded by fertile agricultural lands. At about 10 km north of the town, the Yezin Dam (for irrigation) exists, and adjacent to it, there is a wide land for agricultural research. Agricultural products such as rice, sugar cane, corn, sesame, peanut, etc. are produced. In addition, in the mountain areas along the Shan State on the east of Pyinmana, and in the mountain areas along the Pegu Yoma on the west, lumbers are produced. Moreover, several factories exist. Thus, this city functions as the collecting and distributing center for the various products.

The town area is divided into four parts by the railways running south to north, and the Nga Like creek running east to west. The parts on the north and southeast of the Nga Like creek are flat, and especially, the southeast parts have well-arranged sections with high population densities. The southwest part is rolling in the geographical shape and has several hills.

In Pyinmana, there are several hundred artesian wells and over 50 deep wells. It appears, indeed, to be blessed with water, but in the dry seasons, the water level in these wells goes below and ultimately water shortage takes place.

Fig. 4.1.1.1 shows population and areas by wards. Fig. 4.1.1.2 shows the ratio of areas by land use purposes.

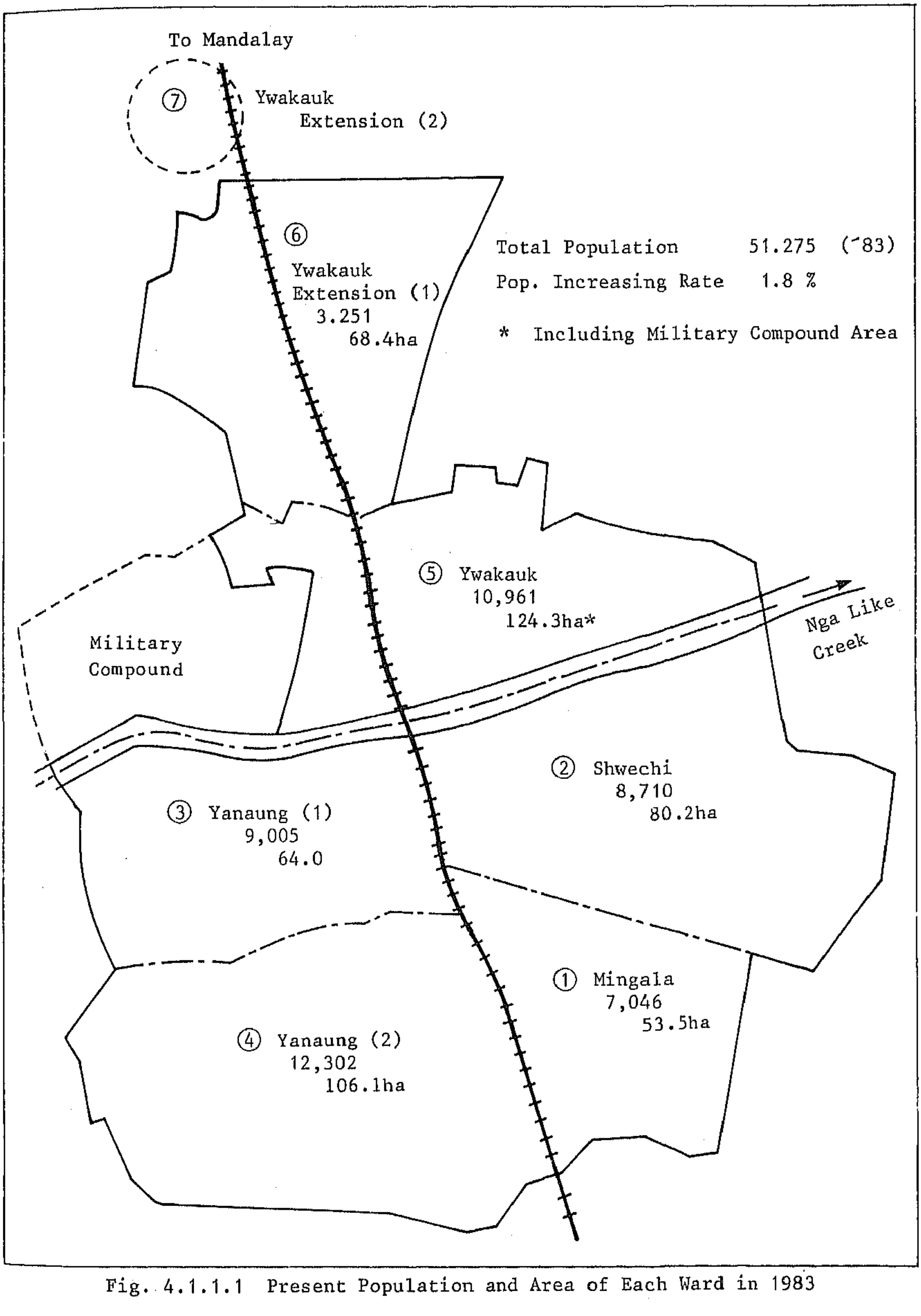
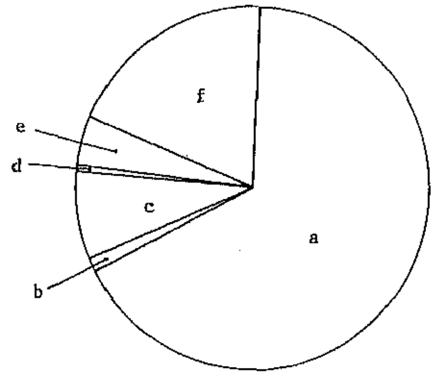


Fig. 4.1.1.1 Present Population and Area of Each Ward in 1983



a)	Residential Area	67.10 %
b)	Cemetery, Garden	1.22 %
c)	Religious Center	8.01 %
d)	Commercial Places	0.50 %
e)	Industrial Areas	4.29 %
f)	Government Buildings (Offices, School, Hospital and Government Buildings)	18.88 %

Fig. 4.1.1.2 Ratio of Areas by Land Use Purposes

4.1.2 Water Resource Development Plan

1) Hydrogeology

(1) Topography and geology

The neighborhood of Pyinmana is a narrow basin contained between the Shan-Tenasserim high land consisting of palaeozoic and granites at about 10 km on the east side and the Pegu Yoma uplift consisting of the Pegu formations of the oligocene and middle and lower miocene of the tertiary period. (Refer to Fig. 4.1.2.1 and Fig. 4.1.2.2.)

Inside the basin, the Irrawaddy formations formed in the upper miocene and pliocene of the tertiary period form hills and are distributed on the west side. The diluvium and alluvium formations formed in the quaternary period form flat low lands and are distributed in the area surrounded by the hills on the east side and the Pegu Yoma uplifts. On these low lands, the Sittang river and its branch rivers flow to the south at slow slopes.

The east side of the railways is sloped at a very slow slope of 2/1000 toward the Sittang river and can be regarded as a flat low land. On the other hand, the west side has hills consisting of the Irrawaddy formations and extending generally in the south-north direction. It is cut by the Ngalike creek, and the north side of the river shows a series of rolling hills, but the south side of the river forms three isolated hills (with altitude differences about 45m). In the low land on the south side, hills are concealed, and the Irrawaddy formations appear at shallow places.

The general layer order is as follows.

Layer order	Age	Features
Alluvium	Alluvial epoch	Surface layer only and thin.
Diluvium	Diluvial epoch	Distributed in flat lands and relatively thin.
Irrawaddy formation	Upper miocene and pliocene	Distributed in depths of hills and flat lands
Pegu formation	Oligocene and middle and lower miocene	Not distributed in Pyinmana

The diluvium consists mainly of sand and gravel layers mixed with clay layers. The Irrawaddy formation consists mainly on clay layers mixed with sand and gravel layers.

(2) Hydrogeology

In the Pyinmana area, the geological structure is complicated in the neighborhood of hills on the east side since there are axes of anticline and fault lines extending in the south-north direction. However, the flat land on the east side slopes slowly and has relatively simple structures.

The existing wells are concentrated on the east side of the railways as shown in Fig. 4.1.2.3. Fig. 4.1.2.4 shows the depth distribution in the south-north direction.

The conditions of these aquifers are as follows.

① Aquifers in the alluvium, distributed at depths of 3 to 9m and having good quality of water. Hand-dug wells are to be dug in this layer.

② The aquifers are considered to belong to the diluvium and Irrawaddy formations, and two aquifers are distributed.

The upper aquifer has upper surface depths of 15 to 25m and increases gradually in depth toward south. This aquifer consists of a pebble layer of about 12m and a gravel layer of about 6m in chickness, and shows electric conductivity (EC) of 80 to 200 μS/cm.

The lower aquifer has upper surface depths of 45 to 60m and tend to gradually increase in depth toward north. These aquifers consist of a pebble layer of about 6m and shows electric conductivity EC of 200 μS/cm.

In the north of the east side, the aquifers as a whole are distributed at deep positions.

③ Tube wells on the west side are distributed on the depressed land contained between hills and their depths are about 35m, approximately equal to the east side.

The existing wells have the well diameter of ϕ2 inch in the main and ϕ4 to ϕ6 inch in some cases. As described above, these wells are used in many cases with upper ones (upper surface depth 15 to 25m) of deep layer ground water aquifers, and in some cases with lower ones (upper surface depth 45 to 60m) of deep layer ground water aquifers. In general, they have as small pumping capacities as 500 to 1000 gph, and this is considered to be ascribable to the well construction (well diameter, pumping system, screen, etc.).

Fig. 4.1.2.5. shows ground water level contours and ground water flow directions according to the existing data. From this figure, it may be regarded that the ground water flows from west to east.

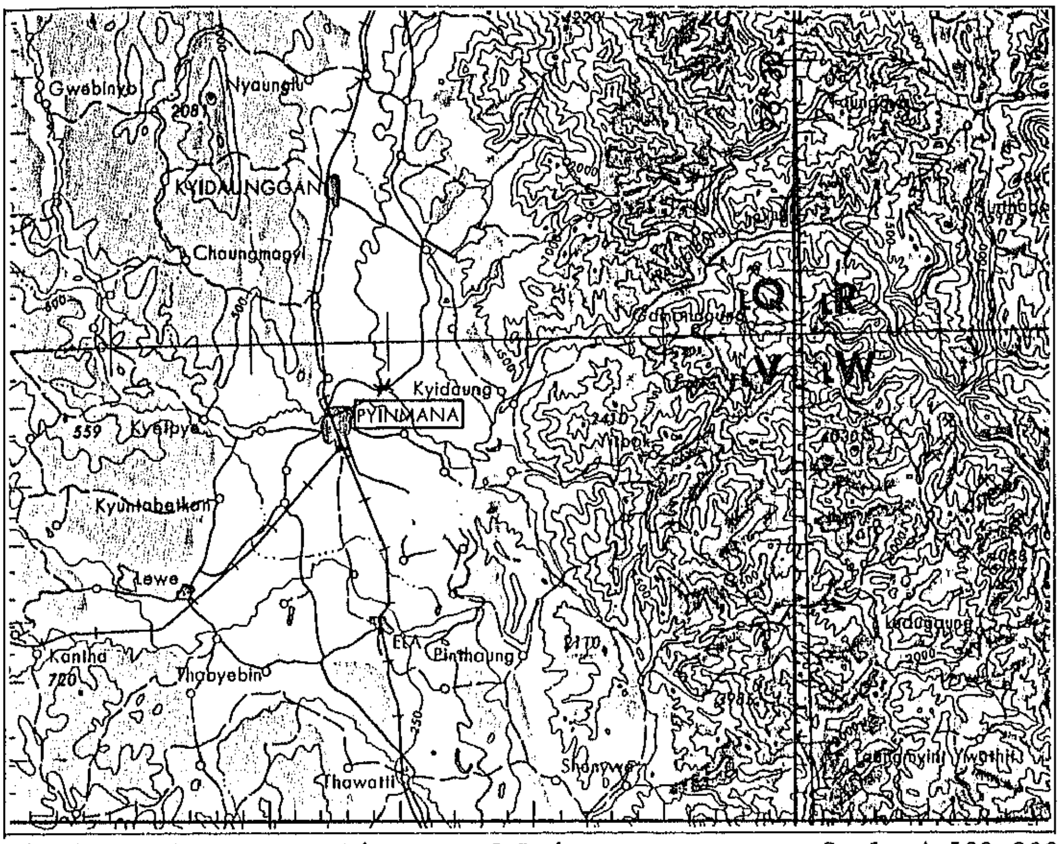


Fig.4.1.2.1 Topographic map of Pyinmana Scale 1:500,000

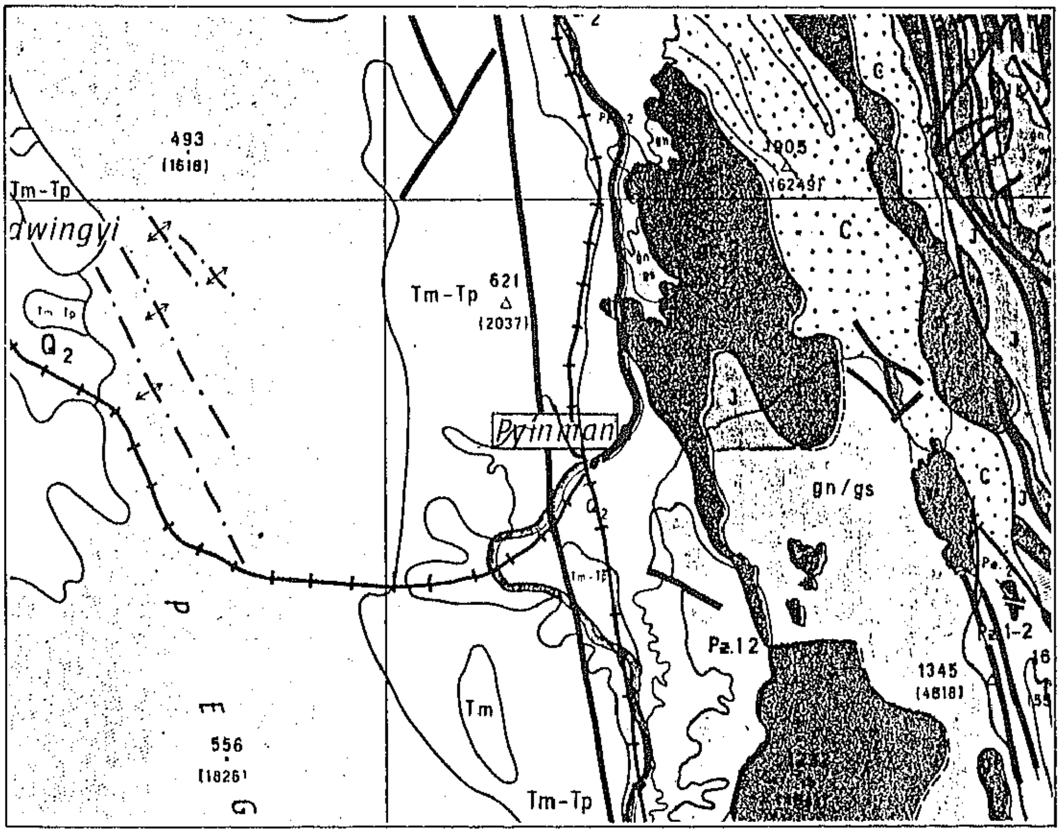


Fig.4.1.2.2 Geological map of Pyinama Scale 1:870,000

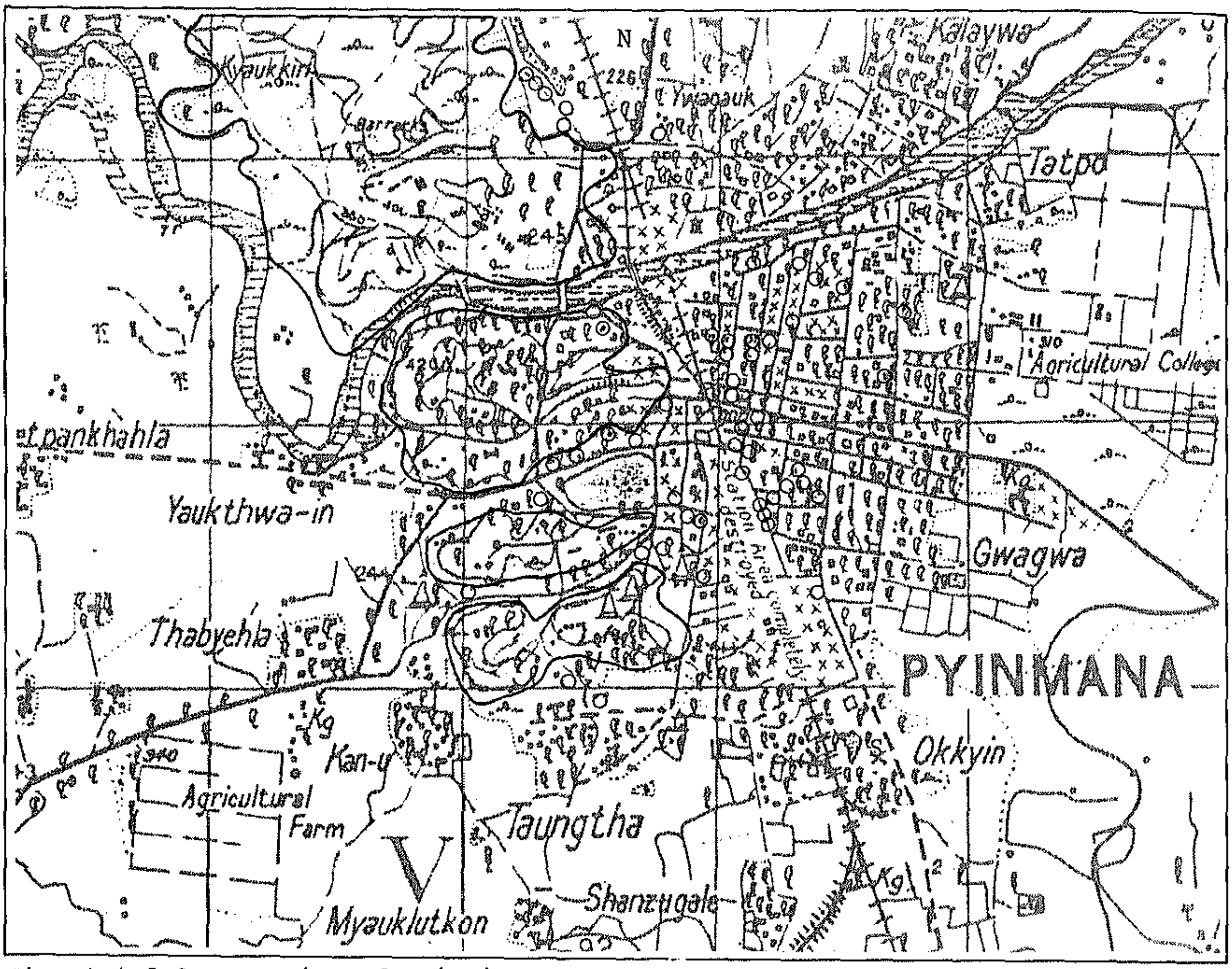


Fig. 4.1.2.3 Location of Existing Tube Wells Scale 1:25,000

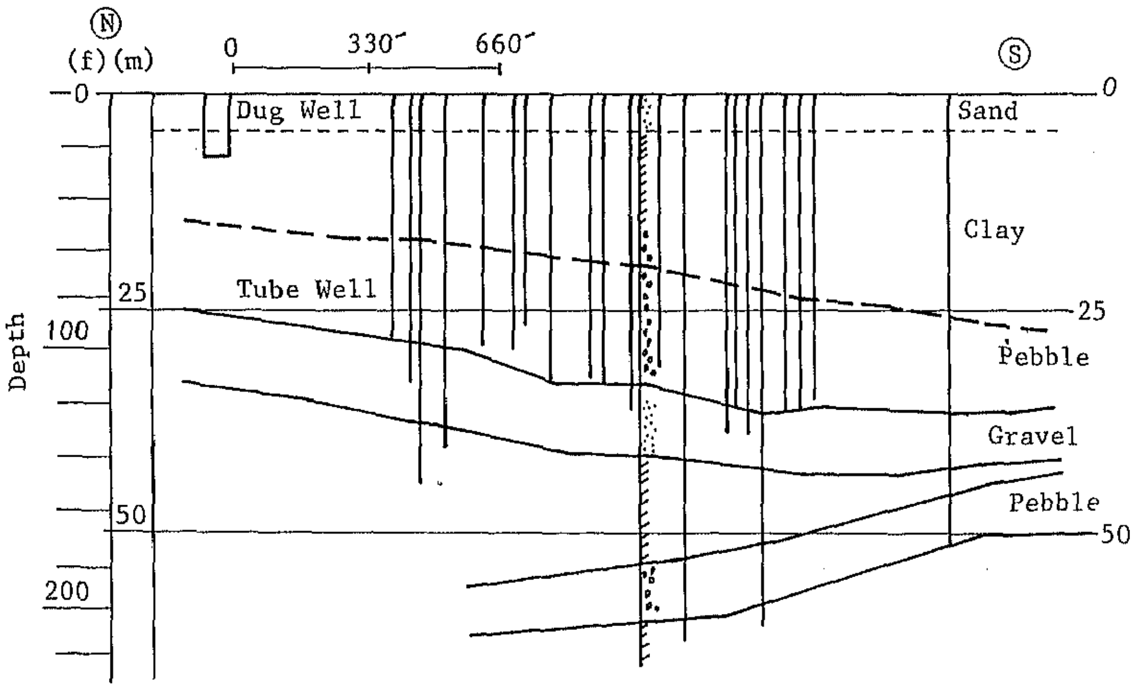


Fig. 4.1.2.4 N-S Section of Existing Tube Wells

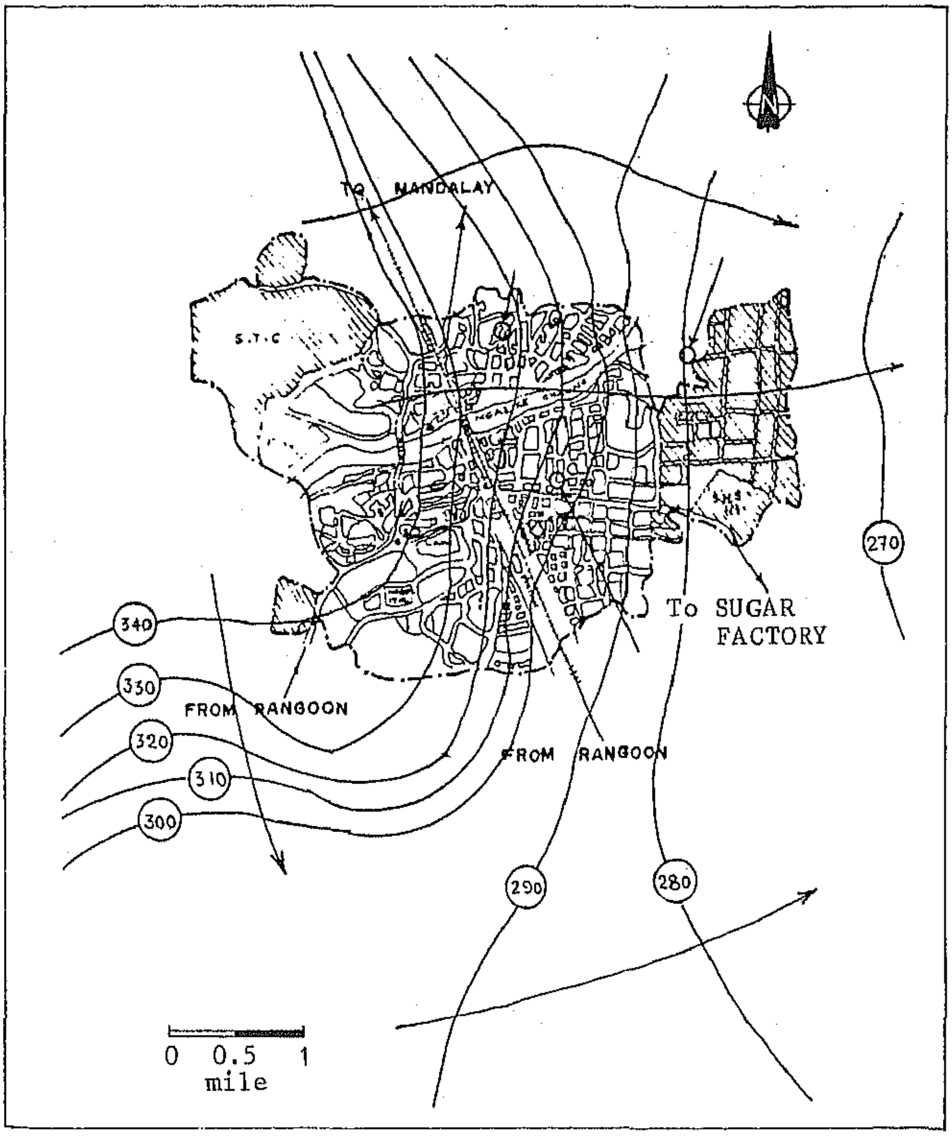


Fig. 4.1.2.5 Contour of Ground Water Table in Pyinmana

2) Aquifer

The aquifers in the Pyinmana area consist of sand and gravel layers of the Irrawady formations as described above.

All these layers are mixed in the clay layers, and have the layer thickness varying with the location.

East side

GL - 16.0 to 20.7m	Sand and gravel
GL - 20.7 to 31.4m	Pebble
GL - 31.4 to 33.5m	Gravel
GL - 54.2 to 60.0m	Gravel

(Good aquifers are up to 23m and occupy about 40% of 60m.)

West side

GL - 0.0 to 7.9m	Pebble or sand or gravel
GL - 13.4 to 56.4m	Sand with pebble
GL - 56.4 and deeper	Clay

(The shallow parts show good aquifers, but the deep parts are impermeable layers.)

On the east side, two good deep aquifers are confirmed, but on the west side, the Irrawady formations are distributed complicatedly and the distribution depth and layer thickness of aquifers vary.

In the Pyinmana area, electric prospecting was carried out at 8 points along two measuring lines on the east side and at 7 points along two measuring lines on the west side, as shown in Fig. 4.1.2.6. The results obtained are shown as the resistivity profile in Fig. 4.1.2.7.

From the analytical results and the existing data, the following may be said.

① The railways running on the east side of the isolated hills form the boundary, on both sides of which the resistivity profile and the layer condition are different, and it is estimated that there are faults.

② The east side of the railways consists mainly of aquiclude layers.

Permeable beds and permeable bed-aquiclude layers are distributed at EL 50m and deeper, and they slowly slope from south to north.

③ The area on the west side of the railways is divided roughly into permeable beds and impermeable beds. In the former, the resistivity is as large as 30 to 70 Ω-m, but in the latter, it is as small as 3 to 5 Ω-m.

The permeability of the Irrawaddy formations seems to be small as a whole since much fine particles are contained.

From the existing data of well logs, the coefficient of permeability is obtained as shown in Table 4.1.2.1.

Table 4.1.2.1 Coefficient of Permeability in Pyinmana

Well No.	Aquifer m (cm)	Draw down S_1-S_2(cm)	Discharge Q (m^3/sec)	Diameter r (cm)	Permeability k (cm/sec)
No. 35	1,250	700	3,750	5.08	6.27×10^{-3}
No. 46	1,525	915	4,375	5.08	4.59×10^{-3}
No. 47	610	610	1,250	5.08	4.92×10^{-3}
No. 48	610	1,968	3,000	7.62	6.44×10^{-3}

The values shown have been calculated in accordance with Thien's formula described in Paragraph 3.2.2(a). The influence area R is assumed as 500m. The average coefficient of permeability is 5.5×10^{-3} cm/sec, being high as compared with the sand layer of the tertiary period.

From the above descriptions, judging from the thickness, permeability and continuity of the aquifers in Pyinmana, it is considered that a considerable discharge rate can be expected. The well depth varies with the location and is estimated as about 80m on the east side and about 50m on average on the west side.

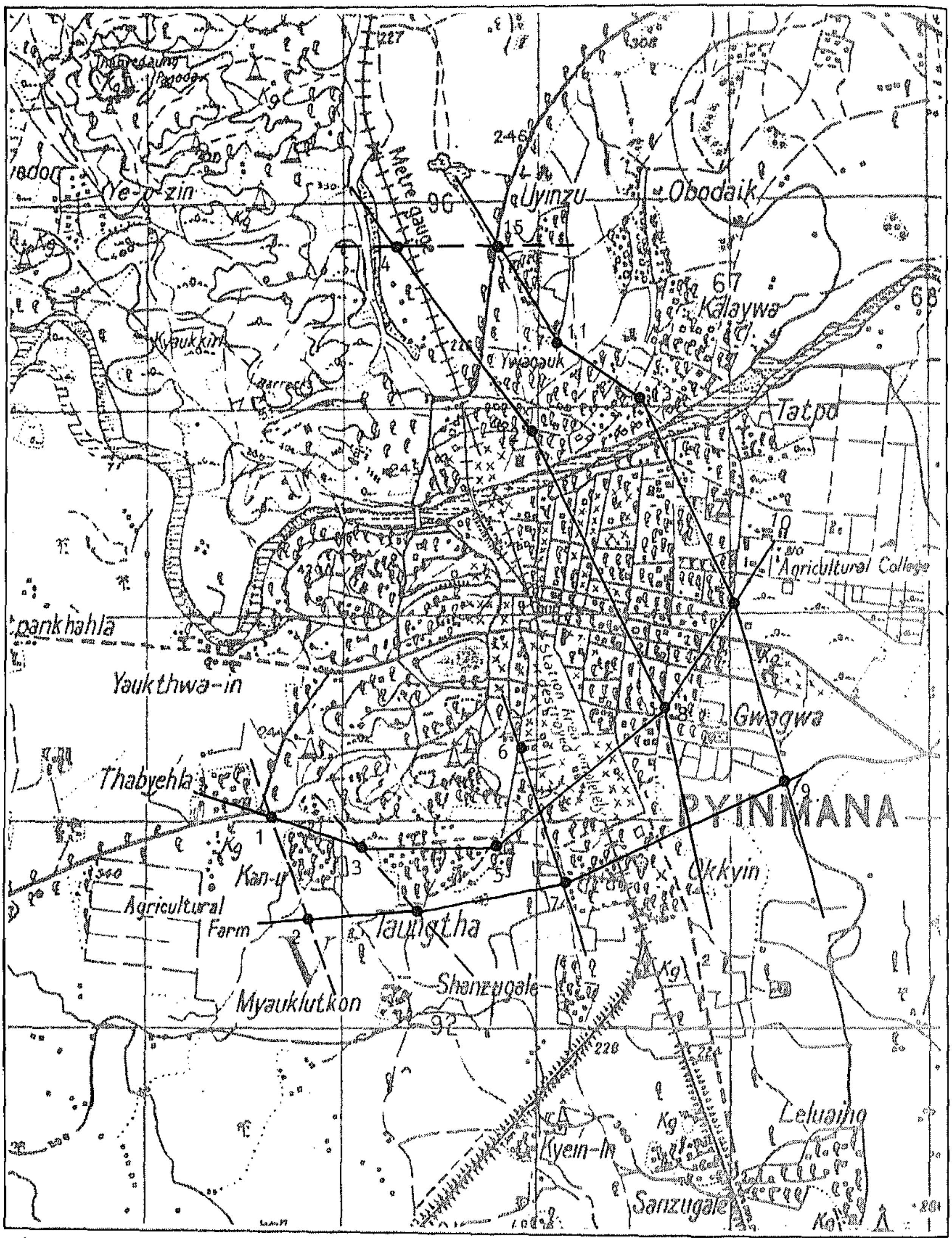


Fig. 4.1.2.6 Location of Electrical Survey Points Scale 1:25,000

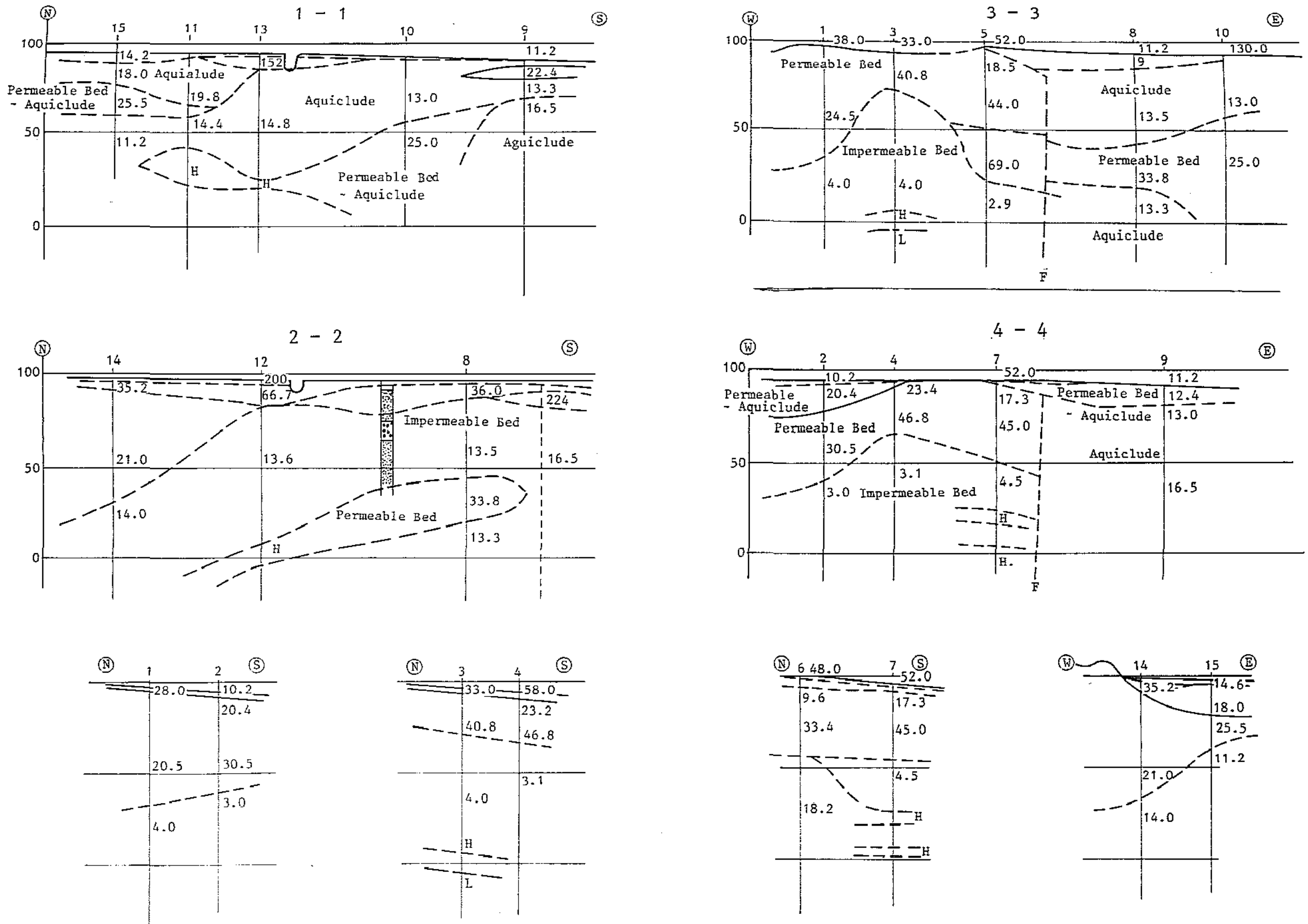


Fig. 4.1.2.7 Resistivity Profiles

3) Ground Water Storage and Water Quality

(1) Ground Water Storage

The annual precipitation P and potential evapotranspiration E are as follows.

Precipitation P = 51.12 inch = 1,298 mm

Evapotranspiration E = Ep x 0.7

= 1,987 x 0.7

= 1,390 mm

(The value in Monywa where average air temperature is nearly equal is used.

Ep' = 78.21 inch = 1,987 mm)

Therefore, considering throughout the year, the ground water recharge G becomes as follows.

G = P - E

= 1,290 - 1,390

= -92 mm

This means that the evapotranspiration exceeds the precipitation and therefore, no ground water recharge takes place. This area has the rainey season and dry season which are discriminated clearly. The ground water recharge in the rainy season 6 months from May to Ocrober) will be considered.

Precipitation P = 46.54 inch = 1,182 mm (Pyinmana)

Evapotranspiration E = 1,117 x 0.7 = 782 (Monywa)

Therefore, the ground water recharge in the rainy season is

G = P - E = 1,182 - 782 = 400 mm

This 400 mm is the ground water recharge.

If this recharge is undertaken in the flat land on the west side only, then the recharge area is about 35 km^2 and the total recharge is given by

$$G = 35{,}000{,}000\ m^2 \times 0.40m = 1.4 \times 10^7 m^3/yr$$

Then, the ground water storage can be obtained from the volume and porosity of aquifers as follows:-

V = A x S x E

where A: subject area

i) West side $A = 1.8 \times 10^6 m^2$

ii) East side $A = 4.0 \times 10^6 m^2$

S: aquifer thickness

i) West side 40m

ii) East side 20m

E: porosity

i) West side 15%

ii) East side 10%

$$V = (1.8 \times 10^6 \times 40 \times 0.15) + (4.0 \times 10^6 \times 20 \times 0.10)$$
$$= 1.88 \times 10^7 m^3$$

This value ignores the ground water make-up and flowout and shows the quantity stored in the present aquifer.

(2) Water Quality

Table 4.1.2.2 and Table 4.1.2.3 show the results of water test. It is considered from these tables that the ground water in the Pyinmana area satisfies WHO standards and will present no problem if used as drinking water.

Table 4.1.2.2 Water Quality

Location	Depth of Well	Temperature °C	PH	EC
No. 8 street	120'	28	6.2	180
"	200	28	-	550
Taung Tha	150	27.5	6.2	82
Taung Tha	140	28	6.8	110
Old Railway SC	210	28	-	180
Pankingon	180	25	8.7	280

Table 4.1.2.3 Water Quality

Item \ Location		EPC	P.P.S.C
1	Appearance	Clear	Clear
2	Total solids	710 ppm	190 ppm
3	Total hardness	75 ppm	100 ppm
4	Permanent hardness	2	7.0
5	Calcium hardness	70	76.0
6	Total iron	0.65	0.32
7	Chloride	9	120
8	PH	86	7.4
9	EC	780	
10	Temperature	28	

4) Discharge Rate per Well, Spacing between Wells, and Well Depth

The discharge rate per well must be grasped by conducting the pumping test. At this point, however, in accordance with Thiem's formula, the discharge rate per well will be estimated. The lowering of water level S is found as 11.8m by the following calculations for the spacing between wells 500m (influence radius 250m).

$$S = R/3000\sqrt{k} = 250/3000 \times \sqrt{5 \times 10^{-5}}$$
$$= 11.8m$$

where R is 250m and k is 5.0×10^{-5} m/sec.

o West side (free ground water)

$$Q = \frac{\pi k\ (H^2-h^2)}{2.3 \log R/\gamma}$$
$$= \frac{\pi \times 4.0 \times 10^{-5} \times (40^2 - 28.2^2)}{2.3 \log 250/0.076}$$
$$= 0.015\ m^3/sec = 972\ m^3/18\ hr$$

o East side (artesian water)

$$Q = \frac{2\pi Dk\ (H - h)}{2.3 \log R/\gamma}$$
$$= \frac{2\pi \times 20 \times 5.0 \times 10^{-5} \times 11.8}{2.3 \log 250/0.076}$$
$$= 0.0092\ m^3/sec = 596\ m^3/18\ hr$$

Therefore, it is considered that in both areas 600 m^3/18 hr can be obtained.

Considering the ground formations, conditions of aquifers, the pumping quantity per well, and the drawdown of the water level, the minimum spacing between wells will be taken as 500m.

Considering the lower limit depth of storage of the aquifer of about 70m, the average depth of production wells will be taken as 76m (6m for sand pit).

4.1.3 Planning The Water Supply Systems

1) Project Area

The dwelling district in the town has increased the population density (about 150 pesons/ha) due to the increase in its population. To cope with this, TDC is developing two new areas in the northern part of the town. (Refer to Fig. 4.1.3.1.) Extension 1 has already been well established, and more than 300 persons dwell there, and Extension 2 is now under planning and it is expected to be constructed in 5 to 6 years time.

However, in this project, the old town and one of two new areas (Extension 1) will be covered as the planned water supply area.

2) Planned Water Supply Population

The planned water supply population is taken as 59200 persons (1991) considering present population 51275 persons (1983) and the average population growth rate 1.8%.

3) Planned Water Supply Demand

Planned water supply demand

= planned water supply population

x planned maximum daily average supply per capita

= 59200 x 105 ℓ/pcd

= 6200 m^3/day

4) Division into Water Supply Blocks

The project area is divided into two parts, south and north, by the Nga Like creek, and further divided finely by the Rangoon Mandalay railways running from south to north. When planning the water supply systems, considering the restrictions by these creek and railways, population distribution or distribuion of available range for planned wells, the project area was divided into four blocks A, B, C and D, each of which is given an independent system.

Table 4.1.3.1 shows the planned water supply population, water supply area, population density and planned water supply rate.

Table 4.1.3.1 Planning Conditions by Blocks

Item / Block	Planned water supply population	Water supply area	Population density	Planned water supply rate
A	23,700 ps	107.1 ha	139 p/ha	2,490 m^3/d
B	17,800	133.7	133	1,870
C	11,800	70.5	167	1,240
D	5,900	68.4	86	620
Total	59,200	442.4	Ave. 133.7	6,220

5) Facility Planning

The available discharge rate of this area is about 600 m^3/d per well as described above. Therefore, the number of required wells by blocks is as follows:-

Block A: 2490 m^3 ÷ 600 m^3 = 4.1 → 4
Block B: 1870 ÷ 600 = 3.1 → 3
Block C: 1240 ÷ 600 = 2.1 → 2
Block D: 620 ÷ 600 = 1.0 → 1

To the water supply system for each block, the basic system shown in the following table will be applied in accordance with the geographical conditions and well installatin district. Especially for blocks B, C and D which are about flat, water distribution from the overhead water tank will be planned. For block A which has hills, the underground water distribution tank suited for the geographical conditions will be installed.

Table 4.1.2.2 Basic System for Each Block

Block	Basic system	Remarks
A	3	
B	2	Incoming well will be omitted because well construction in the water supply area is possible.
C	1	
D	1	

Fig. 4.1.3.1 shows the facility layout for each block based on the above basic system.

6) Outline of Facilities

Table 4.1.3.3 shows specification and quantities for facilities.

Fig. 4.1.3.3 and Fig. 4.1.3.4 show water conveyance pipings and distribution piping networks, respectively. For the planned wells and overhead water tanks, refer to the reference drawings given at the end.

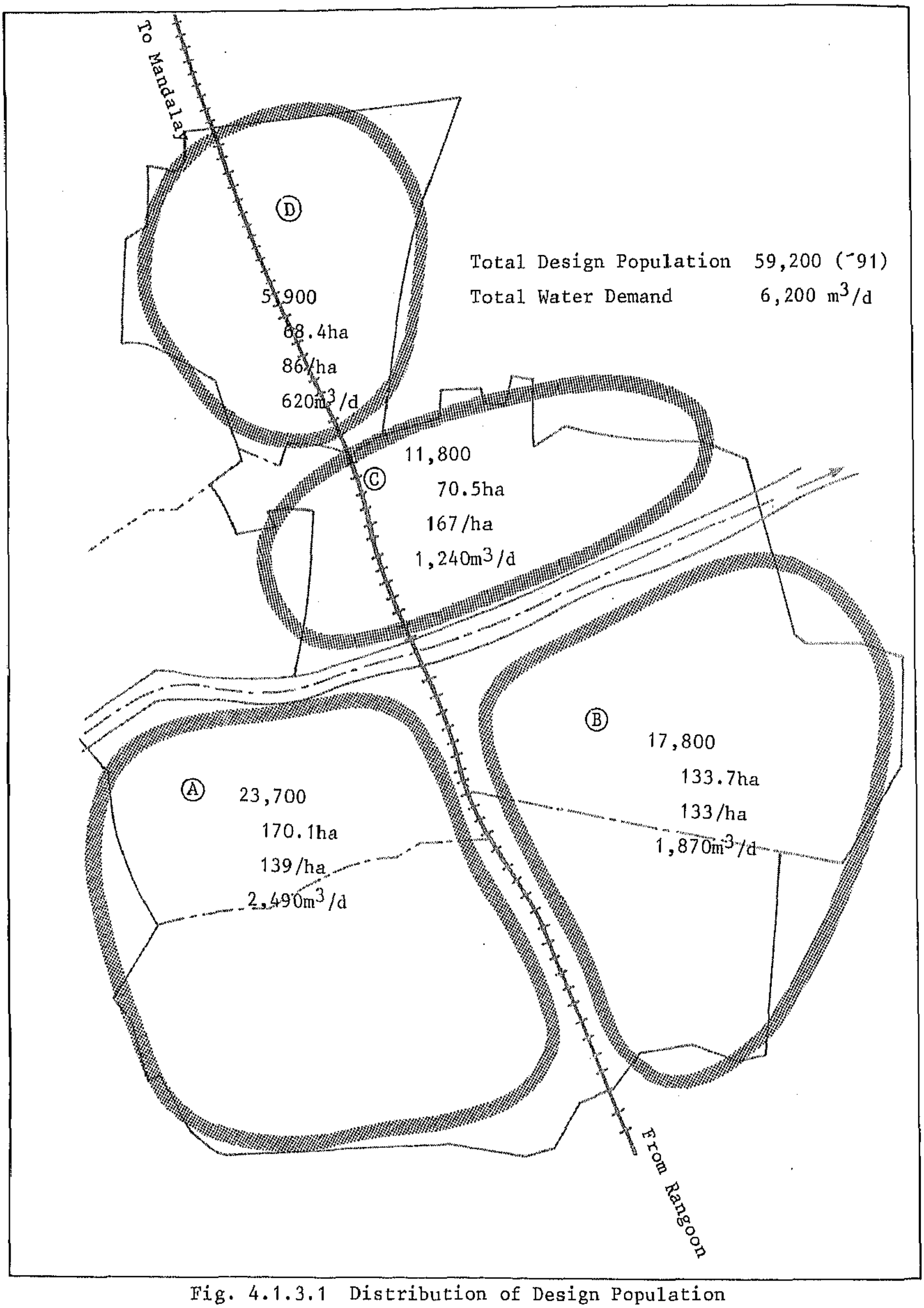


Fig. 4.1.3.1 Distribution of Design Population

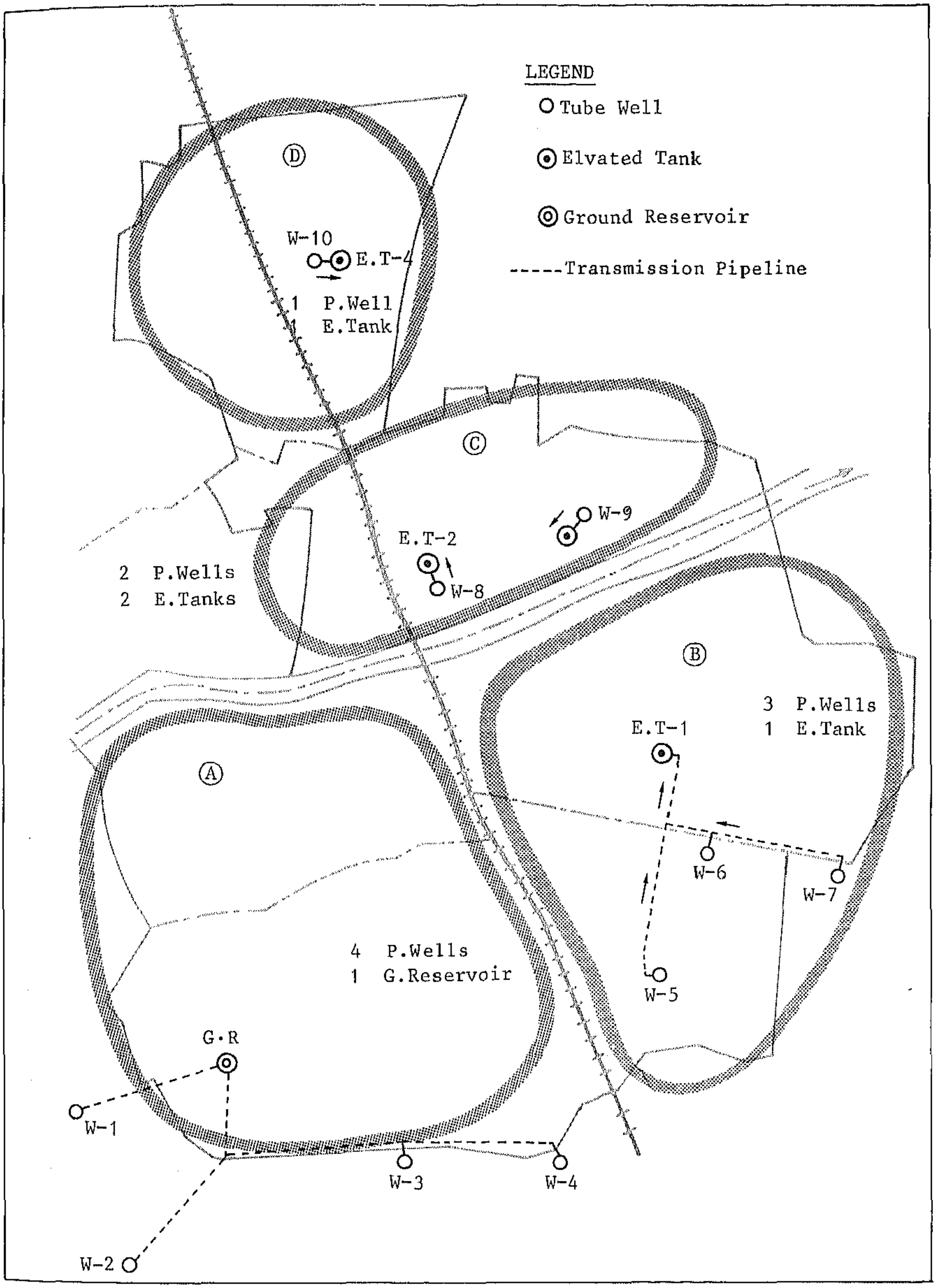


Fig. 4.1.3.2 Layout Plan of Proposed Facilities

Table 4.1.3.3 List of Proposed Facilities

Facility	Item	Classification	No.	Remarks
Water intake facility	Production wells	Planned intake rate 600 to 650 m^3/d φ150mm x H76m	10	Casing H = 54m Screen H = 22m
	Exploration wells	φ150mm x H90m	5	Casing H = 68m Screen H = 22m
	Observation wells	φ100mm x H76	8	Casing H = 66m Screen H = 10m
	Intake pumps	φ100mm x 0.583m^3/min x 10kW	4	W-1 to W-4
		φ80mm x 0.583m^3/min x 14kW	6	W-5 to W-10
	Pump rooms	Brick construction 4m x 4m Building area 16m^2	10 buildings	
Water transmission facility	Water transmission pipes	φ150mm to φ200mm T-type ductile cast iron pipe class 3	3790m	
		Various reducers	1 set	
	Sluice valve	φ150mm to φ200mm	6	
	Air valve	φ20mm	5	
Water distribution facility	Storage tank	Capacity 210m^3 Underground RC construction	1	GR
	Overhead tanks	Capacity 38.9m^3 FRP panel Hight 15.0m Steel base stand	1	E.T-1
		Capacity 12.9m^3 FPR panel Hight 15.0m Steel base stand	3	E.T-2 to E.T-4
	Distribution pipes	φ75mm to φ200m T type ductile cast iron pipe class 3	16,840m	
		Various reducers	1 set	
	Sluice valves	φ75mm to φ200mm	57	
	Air valves	φ20mm	36	
Electrical facility	Substation equipment	3φ4W 11kV/0.4 100kVA, 25kVA	2 sets	
	Transmission line	OW 14□ to 100□ CV 8□ x 4c	27.8km	
		Accessories	1 set	

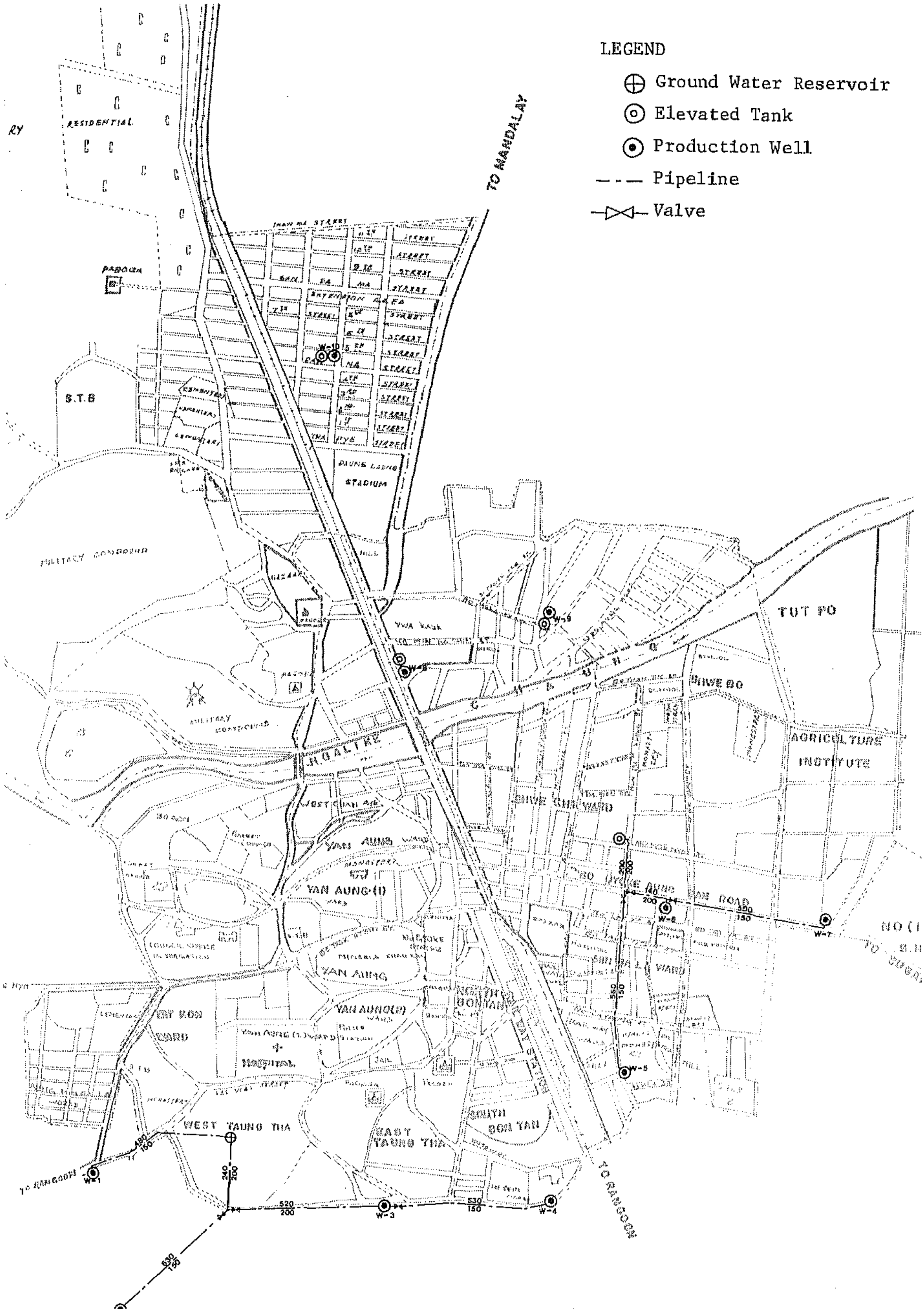


Fig. 4.1.3.3 Layout of Transmission Pipeline

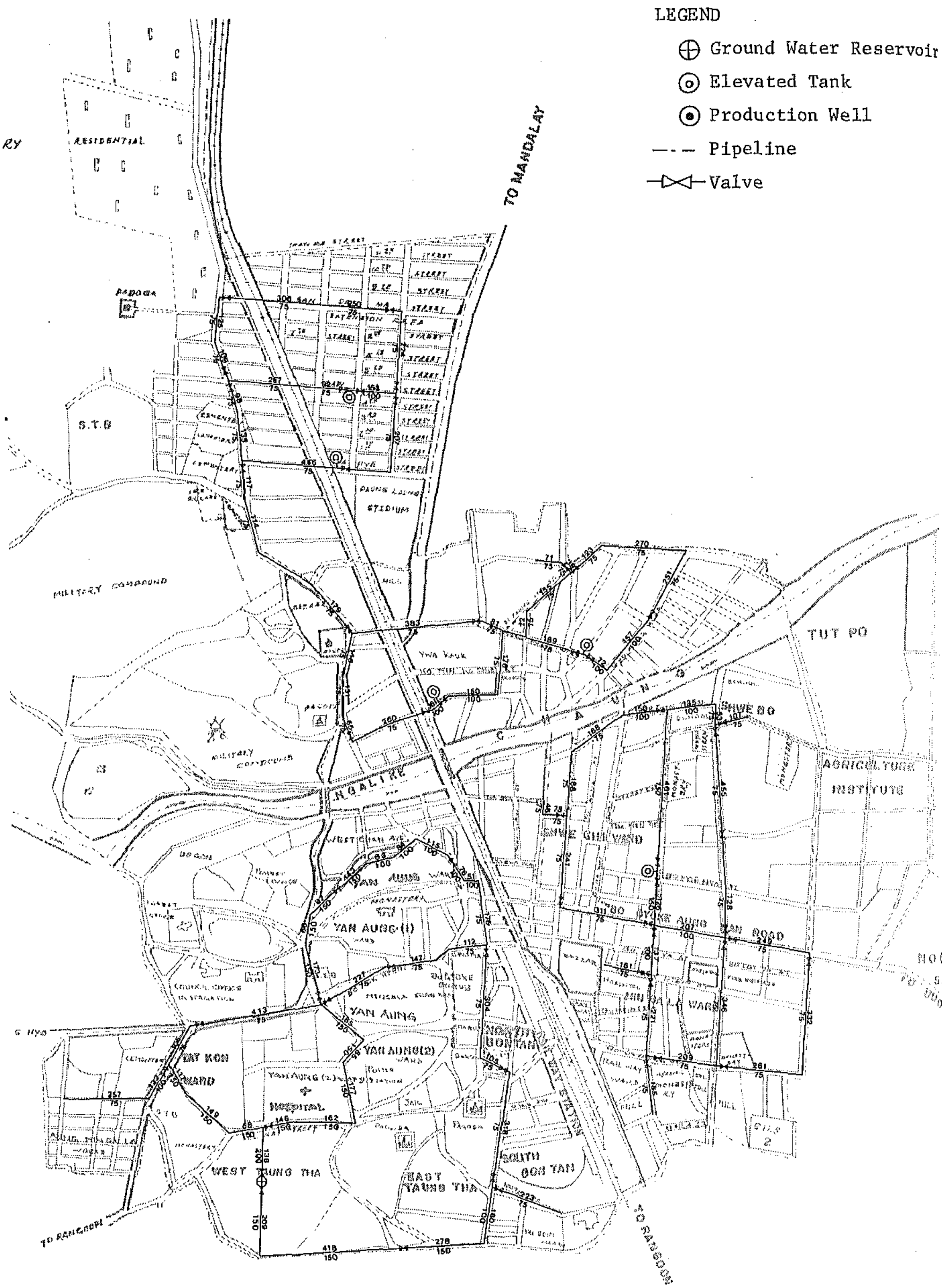


Fig. 4.1.3.4 Network of Distribution Pipeline

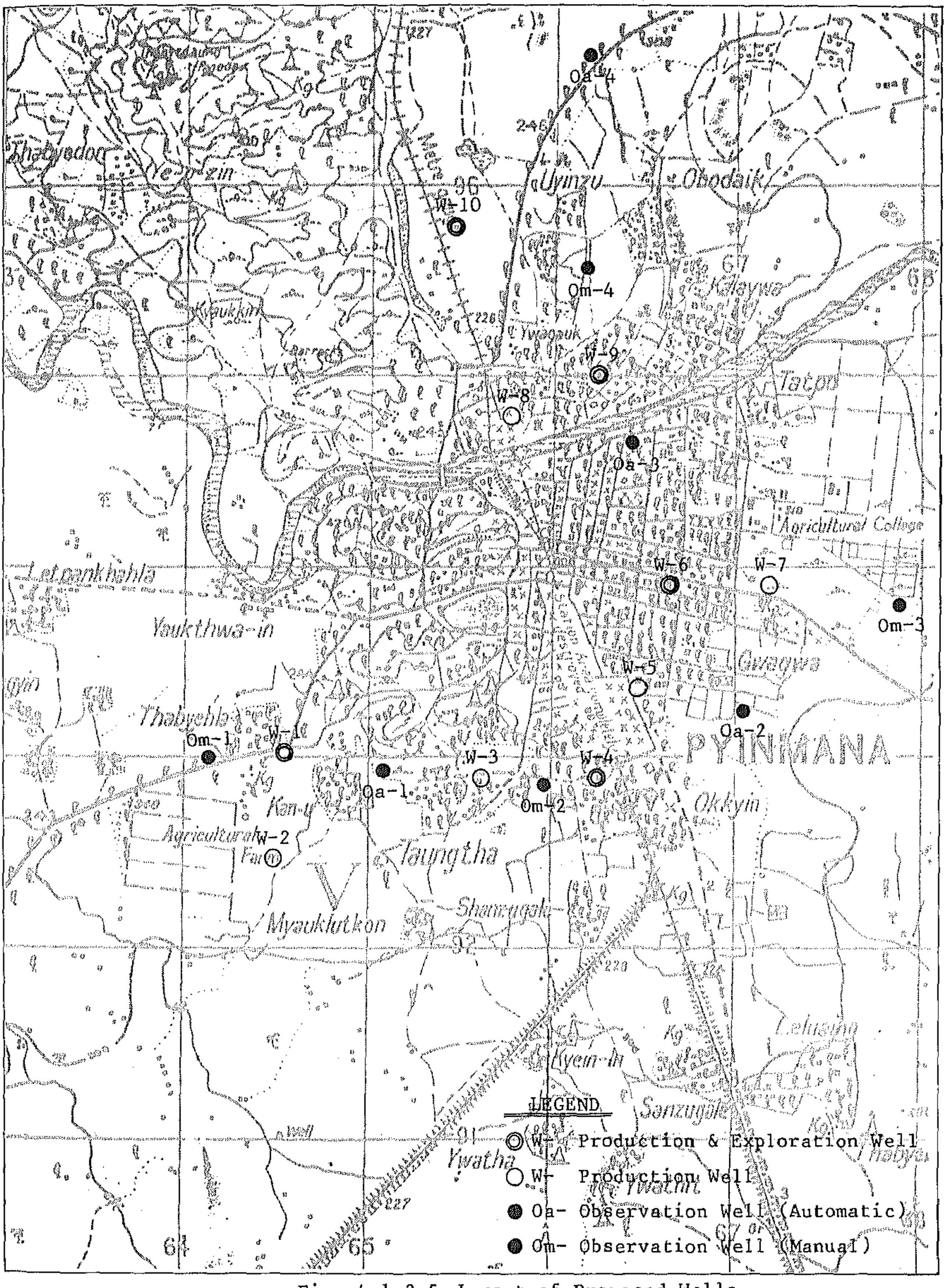


Fig. 4.1.3.5 Layout of Proposed Wells