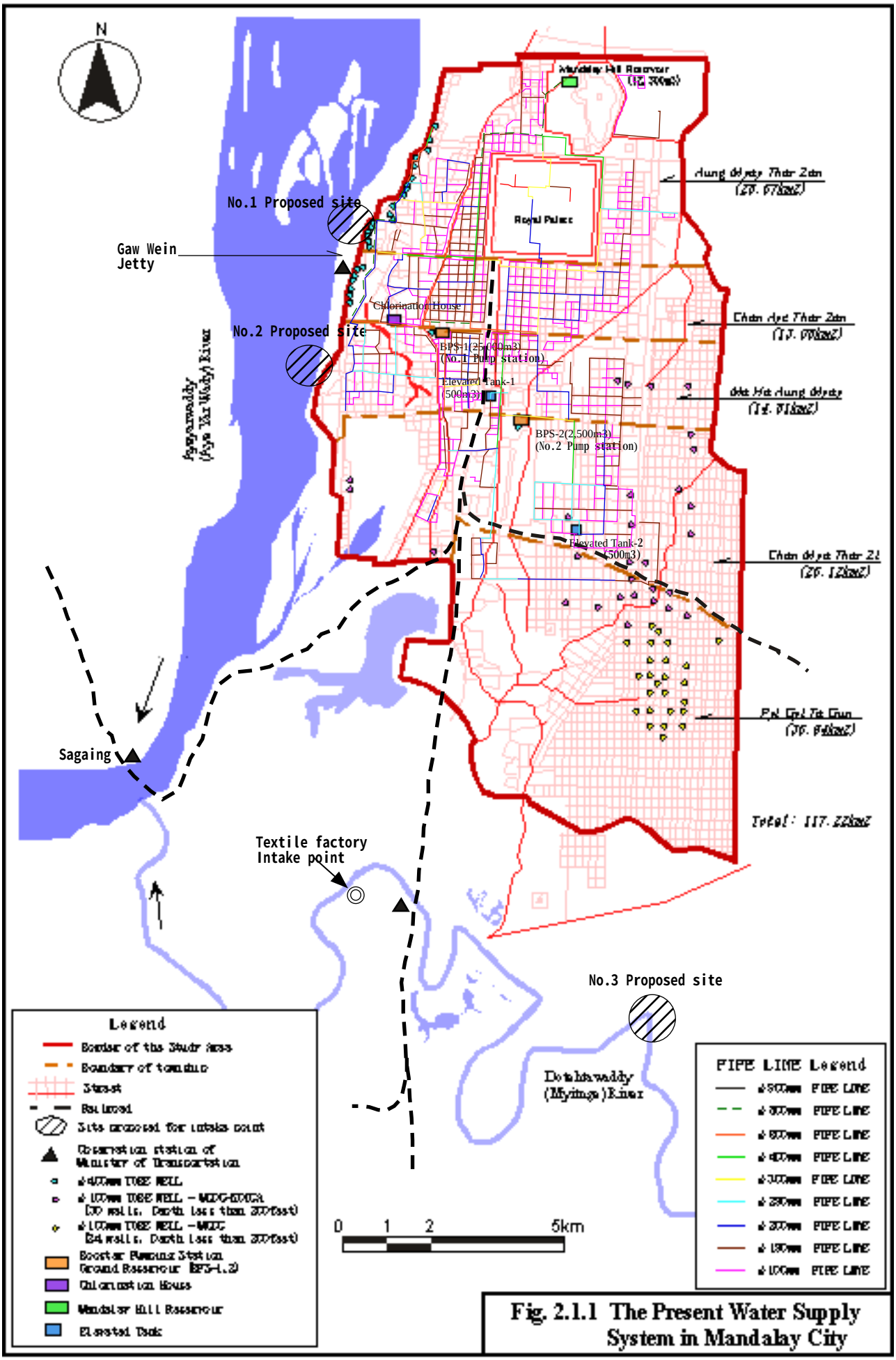

Fig. 2.1.1 The Present Water Supply System in Mandalay City

Ayeyarwaddy River, and one (1) tube well is situated in each compound of the Booster Pumping Stations (BPS1 and BPS2) respectively. Remaining one tube well was located at approximately 1.2 km distant west of the Mandalay Hill Reservoir and the water is sent to the reservoir. Out of 28 tube wells, 19 tube wells were constructed between 1989 and1991 as the ADB Project at first. Subsequently nine tube wells were constructed between 1996 and 2002 by MCDC budget.

2) Disinfection Facilities

After completion of the system, chlorination gas had been injected into the transmission pipe from the tube wells to BPS1. An accident of chlorination gas leakage happened in 1994. WSD failed to repair the chlorination system, then the system has not been functional up to now. Although there have not been any incidences of spreading of water born diseases fortunately for the last 8 years in Mandalay City, officers of the authorities are eager to restore this facility against emergency occasion of the same disease.

3) Booster Pumping Stations (BPS)

The water from the 25 production wells along the Ayeyarwaddy River is transmitted to the ground reservoir with a capacity of five million gallons (22,730 m^3) in BPS1. From BPS1, the water is distributed to the consumers through a network of pipelines. There are three sets of electric motor-drive (410 kW) pumps, each having a diameter of 350mm and capacity of 990 l/s and a set of engine-drive (880 HP) pump with a diameter of 350 mm and a capacity of 1,080 l/s. In the pump house of BPS1 there is an extra space for future installation of three sets of pumps (one is engine-drive type). And there is also a land space for future expansion of a reservoir with a capacity of 12,500 m^3 in the compound of BPS1.

BPS2 is situated at about 2.5 km distant southeast from BPS1 in order to distribute water to the southern service area of the city. The main water source comes from BPS1 and enters into a reservoir with a capacity of 2,300 m^3. There is a production well in this compound and the groundwater is sent directly to the same reservoir.

BPS2 has three sets of electric motor-drive pumps. Among them, two pumps with a capacity of 7.5 m^3/min are properly operated and the other, local product, with a capacity of 2.6 m^3/min is observed deterioration and a heavy leakage from the pump. In the pump house, there is an extra space for future installation of one pump.

4) Distribution Reservoirs

- Mandalay Hill Reservoir

Mandalay Hill Reservoir with a capacity of 12,500 m^3 is situated in halfway up on Mandalay Hill and was built in 1991 by the ADB project. It was intended that water would be stored in the reservoir by an increasing surplus pressure of the distribution pipeline due to a less consumption in the night and then supplied by gravity in daytime to the city. However, the system has not functioned because water never reached the reservoir due to an insufficient pressure of the pipeline. After completion of No.28 tube well in 2002, the water of this tube well is sent to the reservoir and distributed to the city. The RC structure of the reservoir has enough strength to be used in future.

- Elevated Reservoirs

There are two (2) elevated tanks namely, Elevated Reservoir No.1 and No.2, which were erected by the ADB Project in 1991 in order to expand the water service area to the southern part of the city. However, water did not rise to the tanks due to an insufficient pressure of the pipeline. Both tanks are made of steel structure with a capacity of 500 m^3. MCDC constructed a ground reservoir with a capacity of 50,000 gals (227 m^3) within each site. MCDC intends that the water is once received in the ground reservoir then lifted to the elevated tank by a pump. However, this system has not come true yet, because the water never reached the ground reservoir due to an insufficient pressure.

5) Pipeline

- Transmission Pipeline

Transmission pipeline is defined as pipes running between tube wells and BPS1. The total length and diameter of the pipeline is 6,774 m, and the diameter ranges from 400 mm to 900 mm, respectively. Most of the pipes are laid under the ground, whereas some stream crossings are exposed.

- Distribution Pipeline

Total length of the distribution pipeline with a diameter from 200 to 800 mm is over 87 km. Depending on a flow measurement test conducted in this study, the distribution pipes were wrapped by polyethylene sleeve, and they appeared in good condition.

Internal network pipeline is defined as distribution pipes having a diameter of 100 mm and 150 mm. The length of former pipe is 136 km, and that of latter is 65 km, respectively.

- Public Water Supply Point (Water Supply by Small Tube wells)

In the southern area of Mandalay City, there are altogether 54 public water supply points beyond the present water service area. Each system is composed by a small tube well having a four inches (100 mm) diameter of a depth ranging from 20 m to 40 m, a set of airlift pump, and a ground reservoir with a capacity of 5,000 gallons furnished several faucets with its wall. Served population per well ranges from 200 to 400.

24 sets of the same system were constructed by MCDC budget during 1994 and 1995 and recognized as MCDC wells. Then, 30 sets of the same were also constructed by KOICA: Korean International Cooperation Agency, between 1996 and 1997, and recognized as KOICA wells.

2.3 Water Source of Mandalay City

The water source of Mandalay City is groundwater. It is widely recognized that the main water source for catering the future water demand of the city is surface water. However, it is also very important for the city water authority to continue as long as possible the economical water supply service in the city by using groundwater which needs no water processing plant.

Potential of surface water such as the Ayeyarwaddy River flowing along the west side of the city and the Dotehtawaddy River flowing in the south of the city is evaluated for using as the future water source of the City by analysis of flow data for years and water quality test of the river waters. Moreover, the potential of groundwater including exploitable groundwater volume in the city area were analyzed based on the present utilities conditions of groundwater, hydrogeological survey (electrical resistivity prospecting), a test well drilling, monitoring of groundwater levels and water quality of the existing tube wells, and other surveys conducted in the study. These results would be reflected in the Master Plan.

(1) Surface Water Resources

Daily flow data for 26 years were collected on the both two rivers, the Ayeyarwaddy River and the Dotehtawaddy River. Moreover by considering precipitation data, flow volume of the both rivers were estimated as follows,

Table 2.3.1 Evaluation of Ayeyarwaddy River and Dotehtawaddy River

Feature	Ayeyarwaddy	Dotehtawaddy
Lowest Discharge ever Recorded within the Last 26 Years (1973-1998)	1,093 m^3/sec	88 m^3/sec
Mean Discharge within the last 26 Years	6,956 m^3/sec	532 m^3/sec
		Yeywa hydropower dam is under construction and expected to completed in 2005, the minimum flow volume of the river will be controlled at 210 m^3/sec in future.

The water flows of the both rivers are quite enough for the future water demand of Mandalay City (Assuming 180 lpcd for one million population, the total water requirement to draw is estimated about 2.1 m^3/sec).

There was no remarkable pollution in the both river waters, however, quality of the Dotehtawaddy River showed higher content of Dissolved solids, Sediment, Total solids, Turbidity, etc. than the Ayeyarwaddy River. Therefore it was assumed that water of the Dotehtawaddy River would be more expensive than the same of the Ayeyarwaddy River in term of operational cost of Water Treatment Plant.

The Ayeyarwaddy River is situated at within a few kilometers from the center of the city, the Dotehtawaddy River, however, is rather far, over 20 km, from the same. That means the more construction cost will be needed for such long raw water conveyance main pipe.

Based on the above issues, the Ayeyarwaddy River has a higher advantage for using as the water source of Mandalay City until the target year 2020 of the Master Plan. The location of raw water intake plant should be selected from the viewpoint of the least possibility of water pollution.

(2) Groundwater Resources

Based on the collected hydrogeological data and the results of the electrical resistivity prospecting for 110 m to 120 m deep ground conducted by the JICA team, it is confirmed there were a high resistivity zone along the left bank of the Ayeyarwaddy River. The zone was presumed to be abundant in gravel. (see Fig. 2.3.1)

Southeastern part of Mandalay City shows generally low resistivity suggesting fine sand, silt or clay rich layers. In the low resistivity zone, however, two higher resistivity areas exist. These areas are relatively expectable to develop groundwater resources in the low resistivity zone.

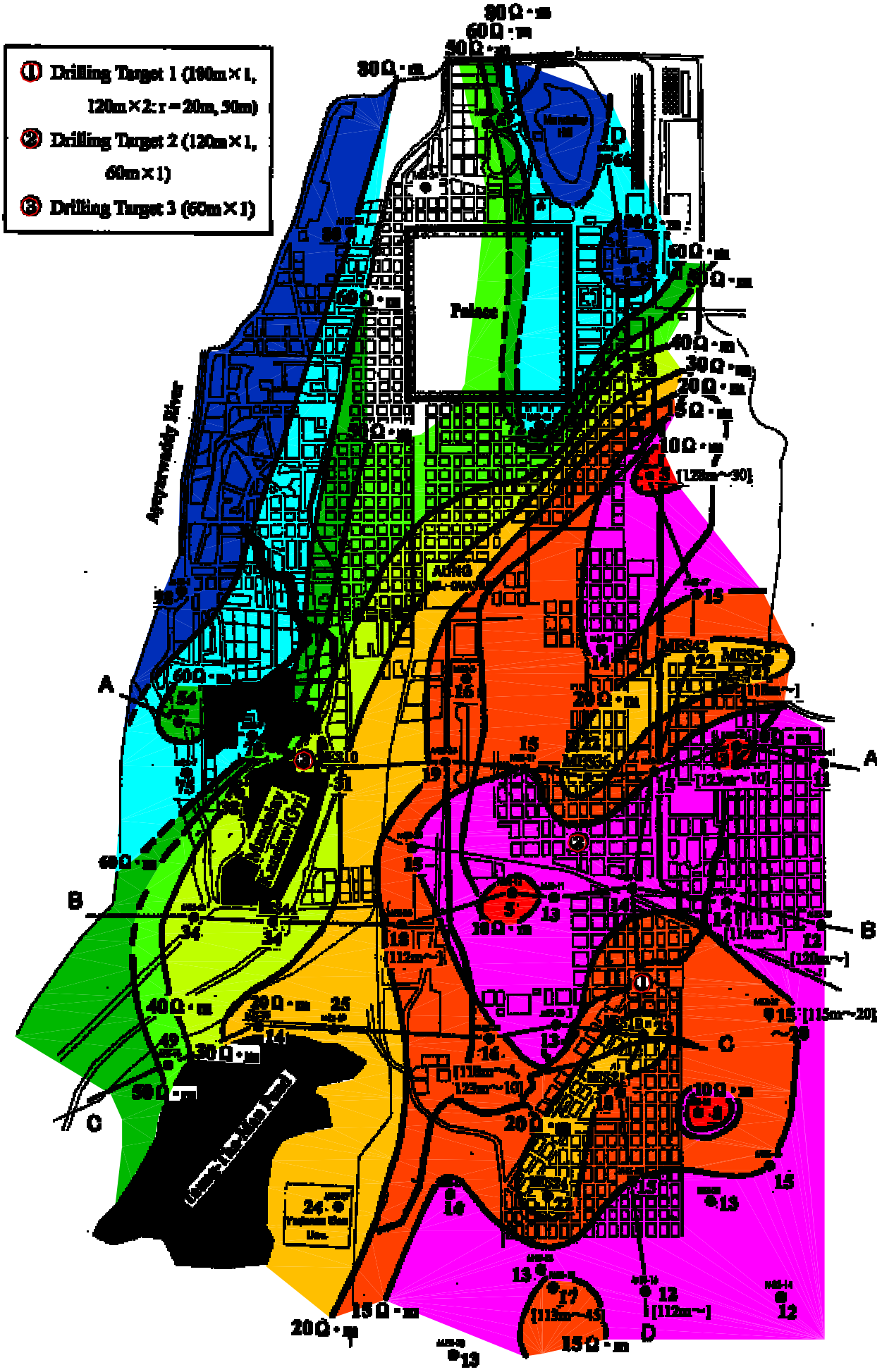

Fig. 2.3.1 110 to 120m Depth Resistivity Distribution

According to the above resistivity structure, drilling targets of the well were considered as follows:

High resistivity zone near the Ayeyarwaddy River is the best location to develop groundwater. Moreover, groundwater recharge from the Ayeyarwaddy River is expected. Generally speaking, southeastern Mandalay City is not very suitable to develop groundwater due to the low resistivity showing the layers abundant in low permeable strata such as fine sand, silt, and clay, except for two higher resistivity "islands" ($\rho \geq 20 \Omega \cdot m$) mentioned above, where groundwater is relatively expectable.

To grasp these geological feature in more detail, monitoring of groundwater level and water quality of the existing tube wells for one year, tube well constructions of a test well and five monitoring well, pumping test at the test well were conducted by the Study Team. The groundwater simulation was conducted after grasping hydraulic conductivity of the total area of Mandalay City through the above pumping test and other hydrogeological analyses.

As the result of the groundwater simulation, it was decided that the additional maximum pumping rates of groundwater were estimated at 36,000 m^3/day in the northwest area along the Ayeyarwaddy River including the present well field and at 24,000 m^3/day in southern area including the industrial zone, then the additional safe pumping rates were recommended at 26,000 m^3/day in the northwest area and 22,000 m^3/day in the south area respectively assuming that 80 % of the maximum pumping rate was optimum yield.

Table 2.3.2 Groundwater Potential

Well Field	Estimated present groundwater used (m^3/day)	Recommendable Additional pumpage (m^3/day)	Total (m^3/day)
Northwest area along the Ayeyarwaddy River	145,000 (109,000 is used by MCDC.)	26,000	171,000
South area including the Industrial zone	25,000	22,000	47,000
Total	170,000	48,000	218,000

Permeability coefficients gained through the hydrogeological survey were 220 m/day in the northwest area including the present well field and 1.3 m/day in the southern area. This difference suggested that the northwest area has 6 to 8 times bigger potential of groundwater than the south area. The water yield in the northwest area was estimated at about 5,000 m^3/day per one well, on the other hand, 800 m^3/day from a well in the southern area.

Groundwater development is more advantageous and suitable as water sources for Mandalay City than surface water considering the present technology level and benefit per invested cost.

Moreover, northwest area can bring the heist profit considering higher groundwater productivity and less construction cost etc. within Mandalay City area. On the other hand, the industrial zone is under developing in southern area, and the present occupancy is still 60% of the total planned area. It is expected that more factories and industries will be set up in the industrial zone in future. Since water supply for industrial purpose is out of responsibility of MCDC at present, the factories in the industrial zone have to supply water themselves by drilling own tube wells. The total amount of groundwater drawn at present is estimated at about 20,000 m^3/day around the industrial zone. The groundwater potential in the southern area, 22,000 m^3/day estimated above, just corresponds to the water demand for the industries in future. Therefore it is recommendable that the groundwater potential in the southern area would not be use as the water sources for MCDC water supply and be kept for the future demand for private use including the industries. Moreover, in order to continue a sustainable groundwater use in future, it is recommended MCDC and enhance a monitoring system of the existing wells in the whole city establish as soon as possible and to obtain authorization for restriction of drawing groundwater of the private wells when a particular negative change of groundwater is observed by the monitoring.

2.4 Water Demand Projection in Mandalay City

Daily average water demand of Mandalay City in future is estimated to increase from 120,000 m^3/day in 2000, to 264,000 m^3/day in 2015, and 305,000 m^3/day in 2020. There is a water shortage of about 24,000 m^3/day on daily average base as of 2001. Therefore it is quite obvious that the prompt countermeasures against water shortage will be required year by year. The water demand estimated is shown in Fig. 2.4.1.

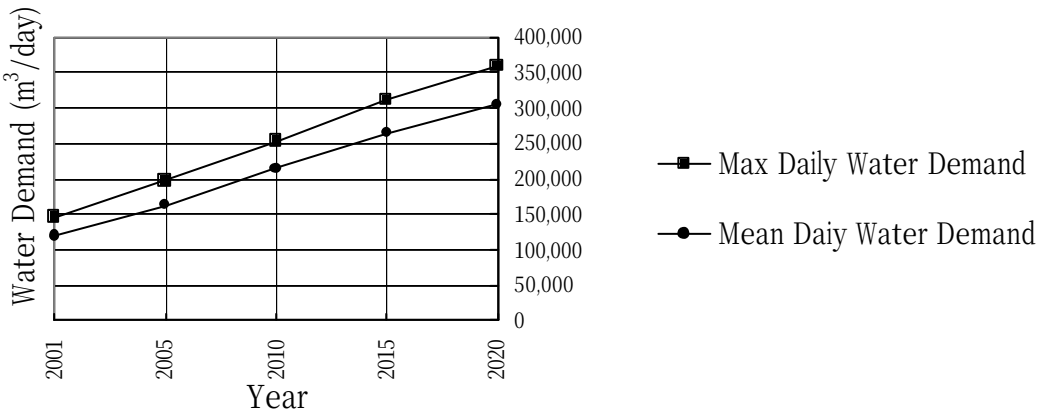

Fig. 2.4.1 Water Demand Projection