4.2 Study and Examination of the Project

4.2.1 Necessity of the Project

Water supply in Greater Kathmandu are afflicted with chronic water shortage and water quality problems. In particular, because the groundwater contains high concentrations of iron, manganese, and ammonia nitrogen, the occurrence of water-borne diseases in Kathmandu city, over more than 50% of the distribution area where groundwater is supplied without treatment is high with 6.8 to 34.3 cases per 1,000 heads. The occurrence of water-borne diseases in Lalitpur city supplied by the Shaibhu system, where water quality is favorable, is 4.7 cases per 1,000 heads. This situations threaten the public hygiene and inhabitant's lives.

The improvement of water supply facilities for the purpose of improving the water shortage and water quality is considered most urgent for the development of social infrastructure, which is an important policy among the development plans of the Nepalese Government.

It is hoped that the countermeasures of improving the situations will be carried out urgently by means of Japanese Grant Aid Assistance.

4.2.2 Related projects

(1) 15YCDP

The 15 year Comprehensive Development Programme (15YCDP) was formed in 1990 on the basis of the study "Service Improvements in Kathmandu, Lalitpur and Bhaktapur and Management Support to WSSC-1990" made with the cooperation of IDA/UNDP. The programme consists of three 5-year plans starting in 1991. A summary and implementation schedule of the 15YCDP are given in Table 4.2.1 and Fig. 4.2.1

The following two projects are in progress under the first 5-year plan (1991 to 1995) of the 15YCDP.

a) Urban Water Supply and Sanitation Rehabilitation Programme (1991 to 1995) (UWSSRP)
b) Greater Kathmandu Water Supply Project (1991 to 1992) (Melamchi project)

1) UWSSRP

The UWSSRP has been implemented with the assistance of the IDA/UNDP, and the detail design and construction supervision will be undertaken by German Water Engineering (GWE). The IDA has already decided to finance the project with 60 million dollars and the UNDP with 6 million dollars. As explained in the 15YCDP, components of the development of water supply in Greater Kathmandu are as follows:

a) Improvement of existing wells
b) Rehabilitation of distribution system
c) Improvement and installation of water meters
d) Improvement of surface water sources
e) Rehabilitation of existing water treatment plants
f) Conjunctive use of surface water and groundwater
g) Construction of treatment plants for the purpose of improving quality of groundwater (Mahankal Chaur and Bansbari)
h) Improvement of distribution system
i) Prevention of leakage.

2) Melamchi project

For the Melamchi project Snowy Mountains Engineering Corporation LTD. (SMEC) has made the feasibility study. This project to introduce water from outside the valley is scheduled to begin in 1991, with completion in 1998 under the 15YCDP. It is planned that water will be supplied from 1999.

At present, the study is to be conducted under the two assumptions: Assuming that Japan implements only two projects (the Project), and assuming that all eight projects proposed by the JICA Water Supply Development Plan are implemented. The study covers the following facilities:

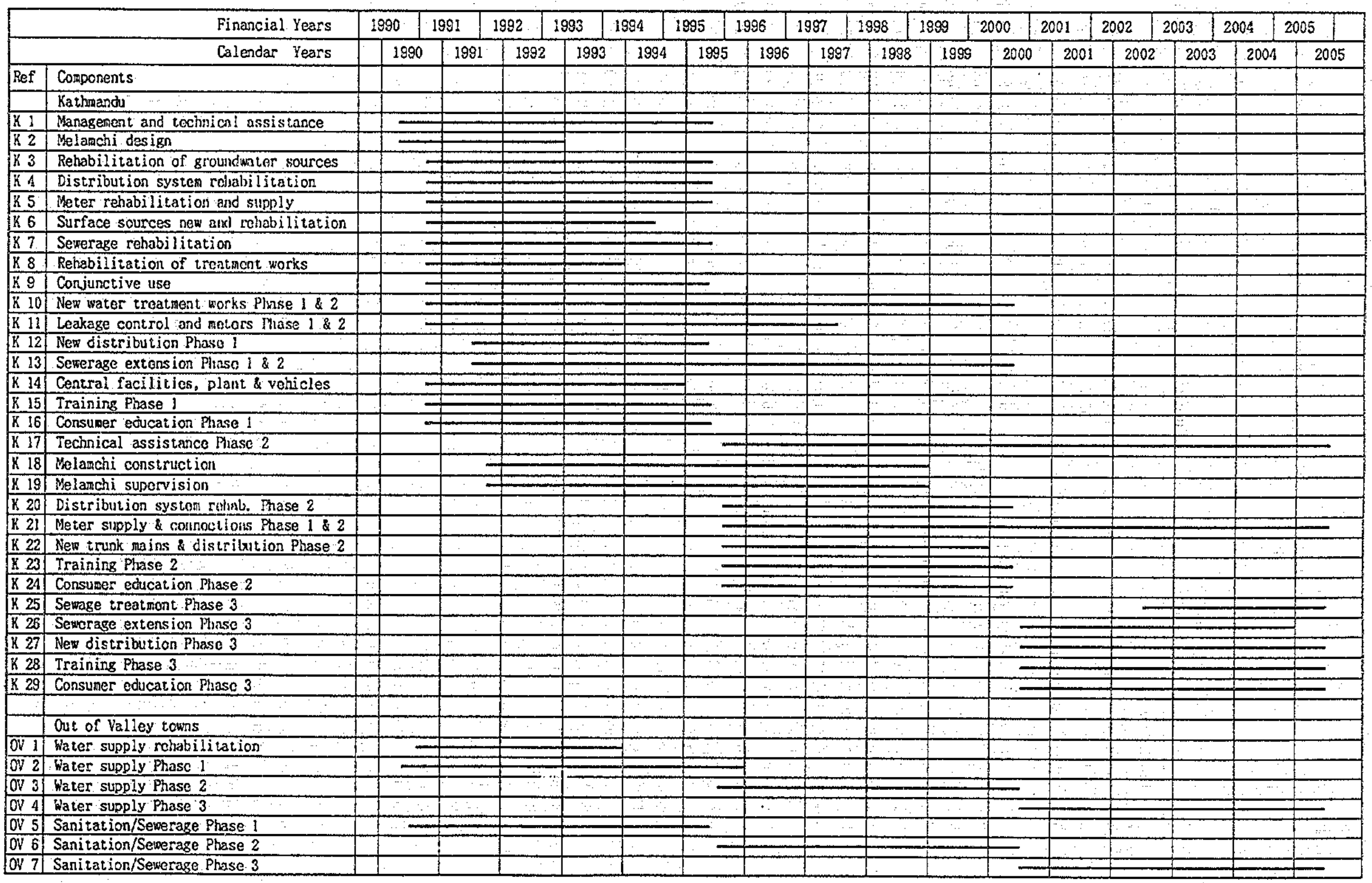
a) Water intake facility (2.6 m^3/s)
b) Water conveyance tunnel (2.5 m in diameter, 27 km in length, 10 m^3/s in conveyance capacity)
c) Balancing reservoir (18 MCM)
d) Treatment facilities (2.6 m^3/s)
e) Transmission facilities (2.5 m^3/s)
f) Distribution facilities (2.5 m^3/s)

The construction cost of the above facilities, excluding the transmission and distribution facilities e) and f), is estimated to be 155 million dollars.

Table 4.2.1 OUTLINE OF 15YCDP

	Description of Components	Cost in NRs million					Local
		Foreign	Local	Tax	Land	Total	(%)
	Kathmandu						
K 1	Management and technical assistance	184.71	72.99	0.00	0.00	257.70	28.32
K 2	Melamchi design	57.00	37.15	0.00	0.00	94.15	39.46
K 3	Rehabilitation of groundwater sources	80.93	8.08	0.62	0.00	89.63	9.01
K 4	Distribution system rehabilitation	220.41	56.21	1.97	0.00	278.59	20.18
K 5	Meter rehabilitation and supply	30.99	1.51	0.30	0.00	32.80	4.60
K 6	Surface sources new and rehabilitation	95.80	30.57	0.69	0.00	127.06	24.06
K 7	Sewerage rehabilitation	74.61	31.81	0.04	0.00	106.46	29.88
K 8	Rehabilitation of treatment works	39.98	6.35	0.23	0.00	46.56	13.64
K 9	Conjunctive use	325.68	58.44	2.27	0.00	386.39	15.12
K 10	New water treatment works Phase 1 & 2	458.89	94.57	2.38	15.06	570.90	16.57
K 11	Leakage control and meters Phase 1 & 2	129.02	57.57	0.31	0.00	186.90	30.80
K 12	New distribution Phase 1	61.15	14.18	0.58	0.00	75.91	18.68
K 13	Sewerage extension Phase 1 & 2	196.05	84.02	0.00	0.00	280.07	30.00
K 14	Central facilities, plant & vehicles	186.28	16.45	1.50	0.00	204.23	8.05
K 15	Training Phase 1	19.60	8.40	0.00	0.00	28.00	30.00
K 16	Consumer education Phase 1	19.60	8.40	0.00	0.00	28.00	30.00
K 17	Technical assistance Phase 2	60.21	23.79	0.00	0.00	84.00	28.32
K 18	Melamchi construction	3,912.17	427.44	2.80	21.00	4,363.41	9.80
K 19	Melamchi supervision	280.98	111.02	0.00	0.00	392.00	28.32
K 20	Distribution system rehab. Phase 2	587.69	166.40	5.00	0.00	759.09	21.92
K 21	Meter supply & connections Phase 1 & 2	131.32	12.48	1.31	0.00	145.11	8.60
K 22	New trunk mains & distribution Phase 2	348.07	75.48	2.37	5.36	431.28	17.50
K 23	Training Phase 2	19.60	8.40	0.00	0.00	28.00	30.00
K 24	Consumer education Phase 2	19.60	8.40	0.00	0.00	28.00	30.00
K 25	Sewage treatment Phase 3	24.43	10.47	0.00	69.30	104.20	10.05
K 26	Sewerage extension Phase 3	314.86	134.94	0.00	0.00	449.80	30.00
K 27	New distribution Phase 3	419.63	148.93	3.83	0.00	572.39	26.02
K 28	Training Phase 3	19.60	8.40	0.00	0.00	28.00	30.00
K 29	Consumer education Phase 3	19.60	8.40	0.00	0.00	28.00	30.00
	Out of Valley towns						
OV 1	Water supply rehabilitation	120.86	39.62	0.95	0.00	161.43	24.54
OV 2	Water supply Phase 1	1,116.65	426.71	6.14	16.63	1,566.13	27.25
OV 3	Water supply Phase 2	1,724.08	405.84	12.80	46.28	2,189.00	18.54
OV 4	Water supply Phase 3	2,267.19	485.68	17.31	50.76	2,820.94	17.22
OV 5	Sanitation/Sewerage Phase 1	27.24	11.67	0.00	0.00	38.91	29.99
OV 6	Sanitation/Sewerage Phase 2	81.62	35.11	0.00	0.00	116.73	30.08
OV 7	Sanitation/Sewerage Phase 3	849.39	364.02	0.84	266.51	1,480.76	24.58
	Total	14,525.49	3,499.90	64.24	490.90	18,580.53	18.84

Fig. 4.2.1 IMPLEMENTATION SCHEDULE OF 15YCDP



(2) JICA Water Supply Development Plan

Although water supply is scheduled to begin in 1999 under the Melamchi project, there are various problems remaining to be solved and it is feared that may not be achieved. Under these circumstances, the JICA Master Plan Study was conducted to form a water supply plan based on the existing water sources and surface water that can be developed within the valley. As a result of this study, eight projects in the following three stages have been proposed as the JICA Water Supply Development Plan:

1) Stage 1

The Plan includes the quality improvement of water from the existing groundwater sources and the development of surface water sources for its conjunctive use. This is considered the most urgent plan from the viewpoints of both water quality and quantity.

a) Mahankal Chaur project

b) Bansbari project

2) Stage 2

Stage 2 covers the improvement of the existing treatment plants and related water supply development plan.

a) Balaju project

b) Lambagar project

c) Sundarijal project

d) Shaibhu project

3) Stage 3

Stage 3 covers the new systems needed for the development of new surface water sources.

a) Manohara project

b) Balkhu project

Appendix 5 gives an outline of the JICA Water Supply Development Plan. The execution plan is as shown in Fig. 4.2.2.

The concepts of this JICA Water Supply Development Plan are as follows:

a) The target year is 2001, when the realization of the Melamchi project is expected.

b) The objectives are to develop water sources to cope with increasing water demand until 2001 and to improve water quality.

c) The existing groundwater should be abstracted within the optimum pumpage in order to conserve the groundwater source and allow the permanent use of it.

d) The water should come from the existing sources and from exploitable surface water within the valley.

e) Conjunctive use should be made of the limited groundwater and surface water which is limited in the dry season.

f) Although the main water source will be the surface water, the finite groundwater source will be used supplementally of during the dry season when the available quantity of the surface water is limited.

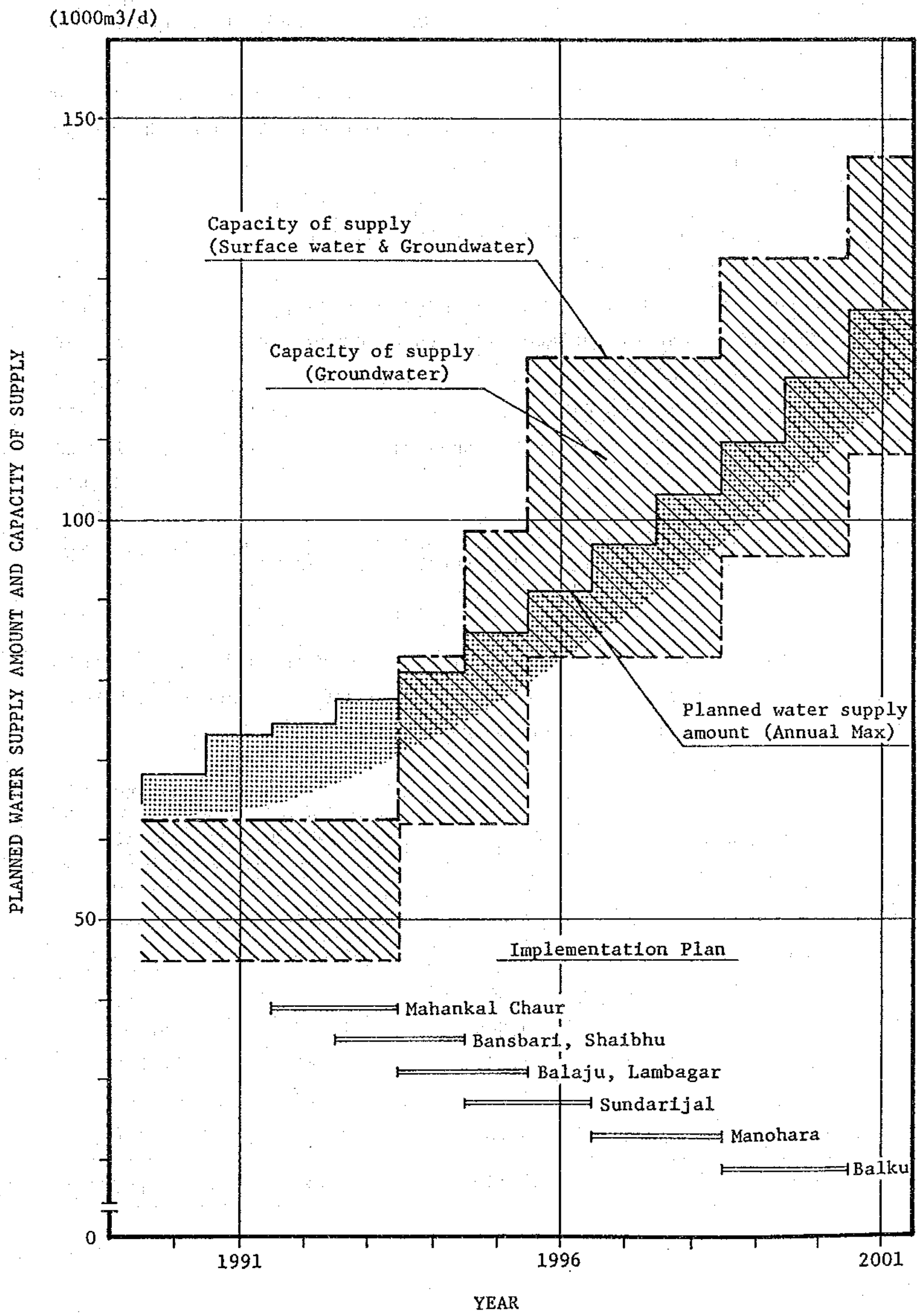
g) Ammonia nitrogen, iron, and manganese are to be removed from the groundwater.

h) The deteriorated existing water treatment plants will be reconstructed to improve water quality.

i) By making the water distribution areas compact, the distribution pressure will be equalized, and variation in the flow rate in the distribution network will be reduced. This will minimize problems of supply quality as well as reducing the failure of supply and leakage.

j) An implementation plan will be made by comparative examination of the effects and economy from the viewpoint of both quality and quantity.

Fig. 4.2.2 IMPLEMENTATION SCHEDULE OF JICA WATER SUPPLY DEVELOPMENT PLAN



(3) Relations between 15YCDP and the JICA Water Supply Development Plan

The following items in the first and second 5-year plans of the 15YCDP compete with the JICA Water Supply Development Plan, the target years coinciding with the later plan.

1)	Development of new surface water sources and rehabilitation of existing sources	616
2)	Rehabilitation of existing treatment plants	969
3)	Conjunctive use of surface water and groundwater	11,959
4)	Construction of new treatment plants (Phase 1)	10,040
5)	Construction of new distribution systems (Phase 1)	2,711
6)	Construction of new distribution systems (Phase 2)	27,110
	Total	53,405

Note) These figures indicate construction costs overlapping with the JICA Water Supply Development Plan (Unit: Thousand US$)

If the JICA Water Supply Development Plan is divided into treatment plants (including the development of water sources) and distribution facilities, the construction costs are as follows:

(Unit: Thousand US$)

	Project	Treatment	Distribution	Total
1)	Mahankal Chaur	13,970	-	13,970
2)	Bansbari	10,850	980	11,830
3)	Shaibhu	1,860	2,020	3,880
4)	Balaju	4,150	-	4,150
5)	Lambagar	6,080	1,980	8,060
6)	Sundarijal	5,980	4,580	10,560
7)	Manohara	6,020	4,360	10,380
8)	Balkhu	5,720	2,810	8,530
	Total	54,630	16,730	1,360

The UWSSRP and the JICA Water Supply Development Plan, on which the Project is based, compete and overlap with each other in the water supply development target up to 2001, the target year of the Melamchi project. Accordingly, it is necessary to clarify the components which can be shared between the UWSSRP and the JICA Water Supply Development Plan, and the effects of the plans should be made manifest even if partially, as soon as possible.

Also, because the NWSC is anxious about the procurement of funds of which is estimated 360 million dollars, for the 15YCDP's water supply and sanitation development plan for the valley. It is attempting to adjust the overlapping items to achieve the maximum possible effect by putting the limited funds to best use. It expects Japanese Grant Aid Assistance will be further expanded.

(4) Adjustment between UWSSRP and JICA Water Supply Development Plan

A water supply development plan with the target year of 2001, when the realization of the Melamchi project is expected, should have the following purposes by making adjustment of the competitive and overlapping UWSSRP and the JICA plan as mentioned in (3).

1) Development and improvement of water sources in the valley basin to cope with the water demand.

   a) Improvement and rehabilitation of existing wells.
   b) Improvement and rehabilitation of existing surface water sources.
   c) Expansion and improvement of existing surface water sources.
   d) Development of new surface water source of conjunctive use with existing groundwater source.
   e) Development of new surface water sources.

While the water demand was 62,800 m^3/d in 1989, it is expected to be 126,200 m^3/d in 2001. Provided that optimum groundwater management is carried out for the purpose of utilizing a groundwater, as an important water resources, the maximum production capacity of the present facilities should be only 54,800 m^3/d (water supply amount), so that water sources must be expanded and developed to secure the rate of 71,400 m^3/d.

The surface water source within the valley can supply sufficient water in the wet season, but available water in the dry season falls off rapidly, resulting in imbalance of the available water supply amount among the water supply systems. Therefore, it is necessary to develop the sources in the most economical way as a whole of the waterworks, by thoroughly examining the construction of reservoir to store surface water in the wet season for the sake of supplementing water supply sources and the regulation of water transmission between distribution areas in order to correct the imbalance as above-mentioned.

2) Construction and rehabilitation of treatment plants for existing and new water sources

a) Reconstruction of existing Sundarijal treatment plant
b) Reconstruction of existing Balaju treatment plant
c) Rehabilitation of existing Shaibhu reservoir
d) Quality improvement of existing groundwater source
e) Construction of treatment plants for conjunctive use of existing groundwater and new surface water
f) Construction of treatment plants for new surface water source

The treatment plants of a) and b) above were constructed in the 1960's, about 30 years ago, and their function is paralyzed. The function is almost impossible to be restored. It is necessary to reconstruct them urgently to allow proper treatment.

The plant of c) above requires the improvement of the sterilization system and so forth.

The source of d) requires the removal of ammoniac nitrogen, iron, and manganese contents as groundwater in the northern part of the valley contains these impurities of high concentrations.

With regard to e) above, since the ratio of the treatment amount of groundwater and surface water has a high level of monthly variation, the treatment plants should have capacity that can follow this variation.

With regard to f) above, the treatment facilities should follow the monthly variation in water quantity and quality.

3) Improvement and rehabilitation of existing distribution facilities and service installations

As the distribution facilities have been extended at random to meet increasing water demand and to expand the distribution areas since the opening of the waterworks in 1896, these facilities are extremely deteriorated and the water pressure in the distribution areas is not uniform because the demand distribution and distribution systems are not balanced. Resulting in poor discharge at the connections and water leakage. Also, the corrosion tendency has become the same time because the groundwater contains a high concentration of iron, manganese, and ammonia nitrogen, resulting in the corrosion and blockade inside of the distribution pipes. The service installations have also deteriorated and does not work properly. Serious leakage and the lack of meters result in greater water leakage and wastage, as well as being a factor in the managerial difficulties of the waterworks. Under these circumstances, the following improvement and rehabilitation are needed for the existing distribution facilities and service installations:

a) Cleaning and replacement of existing distribution pipes
b) Prevention of leakage from distribution network and service installations
c) Improvement of the water supply equipment, particularly the general installation of water meters
d) Development of a distribution network meeting the supply system as described below

4) Development of a distribution system to cope with increasing water demand and demand distribution.

As of 1989, the rate of 62,800 m^3/d was supplied, and it is assumed that this will reach 126,200 m^3/d in the year of 2001. Therefore, the present distribution system will no longer be able to distribute the water uniformly. In other words, if two times of water amount is to be distributed over the same area, the disparity of water pressure over the distribution area will be 3.6 times greater, resulting in water leakage, poor discharge at connections, and accidents such as bursting of aged pipes and service installations.

To provide distribution system that maintains the same conditions (water pressure balance) as those in 1989, the distribution area must be divided into 1/3.6. Making the distribution area compact will make the pressure uniform and reduce variations of water flow in the distribution network, thus bringing about uniform supply and preventing further deterioration in water quality.

5) Separation of water transmission system and distribution system

At present the water transmission system and the distribution system are not separated, so that the lack of uniformity in the pressure of distributed water and variations of flow are considerable. This is the cause of water leakage, poor discharge at connections and water quality problems. It is necessary to make the distribution system compact as described in Item 4) above, and at the same time to separate the of water transmission pipeline concerned to the distribution area from the distribution network.

Moreover, to uniform the water pressure further and to reduce variations of flow in the network, the distribution area should be fixed, so it is necessary to plan a suitable mutual connection pipeline which will supplement the transmission amount to each fixed distribution area.

6) Conformity as one stage of a long term water supply development plan

The water supply development ending in 2001 constitutes the first stage of the long-term water supply and is an important role of the long-term water supply. It is necessary to have an conformity on the implementation plan, adjusting, clarifying its overlaps in the 15YCDP of which mentioned above, especially between the UWSSRP and the JICA Water Supply Development Plan for the purpose of making a great deal of effect on the improvement for the waterworks which is to be carried out from 1991 to 2001 with limited funds.

On the basis of these basic ideas, the UWSSRP is already being implemented with the financing of 66 million dollars from the IDA/UNDP in the following areas:

1) Improvement and rehabilitation of existing water sources
2) Improvement and rehabilitation of existing distribution pipes and service installations
3) Improvement of water distribution systems including the construction of new reservoirs aiming at making the distribution area compact.

The Government of Nepal strongly wishes to have Grant Aid Assistance of Japan to start improving water quality and developing new water sources by setting up treatment facilities for existing water sources and new water sources other than those described above. This Project is to improve groundwater quality, develop surface water sources to be used conjunctively with existing groundwater, and construct related treatment plants; the Government of Nepal also hopes to implement the remaining projects as proposed in the JICA Water Supply Development Plan under Grant Aid Assistance of Japan.

(5) Suggestion for making long-term water supply plan

The Melamchi project is a long-term water supply plan covering demand for 30 years after the year 2001. Since the investigation work will be enormous, full study and adjustment for the following points are needed at least;

a) Forecast of water demand
b) Positioning of the water supply development plans in the period until completion of the Melamchi project
c) Conformity with existing distribution systems

1) Forecast of water demand

The population projection has so far been based on census data taken every 10 years, with presumption made by taking into account a predicted natural increase and an increase due to social factors. Although this is considered acceptable in the case of relatively short-term plans as in the past cases. However, the predictions of a population increase based on the logistic curve method on the basis of the estimate of the saturated population from physical and economic potentials of Greater Kathmandu are thought suitable in the case of a long-term plan exceeding 30 years.

Here we attempt to estimate the saturation population in view of the physical potential: The total area that can be supplied with water including Greater Kathmandu and surrounding areas is about 151 km^2, and this may be broken down as follows:

- Inside the ring road (Greater Kathmandu urban area)	43.2 km^2
- Outer area adjoining to ring road (1 km outside the ring road)	27.5 km^2
- Flat areas other than the above	80.3 km^2
Total	151.0 km^2

According to a forecast in JICA's Master Plan Study, the population of Greater Kathmandu in 1991 was to be 486,000. Since the border of Greater Kathmandu practically coincides with the ring road, the population density of the urban area by using the area of 43.2 km^2 is 11,250 persons/km^2.

Even at present, the Greater Kathmandu urban area is much overpopulated and further population concentration seems difficult. Furthermore, most buildings in Nepal are made of brick and it is difficult to build multi-storied housing. However, if gathering and medium-storied housing will bring about a population concentration of about 14,500 persons/km^2, or about 1.3 times the present figure.

With regard to the outer area adjoining to the ring road (within 1 km outside ring road), most of the land is currently used for agriculture mainly as paddy fields. It is expected that the population density will rise to the level of the present urban area in the future (11,000 persons/km^2) as the urban area expands. About the flat areas other than the above, there are areas of which is very difficult to make land for housing use because of undulations, so that the population density will probably rise to the upper limit of about a half of that of the present urban area (5,000 persons/km^2).

From the above consideration, the saturation population of the service area in Greater Kathmandu and surrounding areas is estimated to be the following:

- Inside ring road	
43,2 km^2 x 14,500 persons/km^2 =	626,400 persons
- Outer area adjoining to the ring road	
27.5 km^2 x 11,000 persons/km^2 =	302,500 persons
- Flat areas other than the above	
80.3 km^2 x 5,000 persons/km^2 =	401,500 persons
Total	1,330,400 persons

Thus the total saturation population in the available service area is estimated to be about 1.35 million and the average population density in the area will then be about 9,000 persons/km^2. This density is about 80% of the present density of the urban area. It is considered that population growth beyond this seems physically impossible.

On the other hand, it is extremely difficult to forecast population based on social and economic factors and it will become necessary to invest a huge amount of money in the development of the social infrastructure to support a population of 1.35 million. Also, as the use of agricultural land is converted to housing in keeping with urbanization, it will be necessary to develop industrial infrastructure and to attract industry in order to absorb the present agricultural labor population and an increasing working population resulting from an increase in population. Therefore, it is necessary to carefully study the importance of Kathmandu as the capital and its social, economic, and geographical conditions and to examine the urban infrastructure development and the adequacy of investment in it. It is also necessary to look into the proper scale of cities including future population on the basis of these studies.

If the saturation population is assumed to be 1.35 million, the forecast of the future population using a logistic curve method proceeds as follows:

Here the constants a and b have been derived from population in 1991 and 2001 estimated in the JICA Master Plan Study and the population in censuses in 1961, 1971, and 1981 using the method of least squares.

$$y = \frac{k}{1 + e^{a-bx}}$$

where, y: Population x-years after base year (1981)
x: Years elapsed from base year
k: Saturation population (1.35 million)
a, b: Constants (a = 1.04608, b = 0.05362)

(Unit: Thousand persons)

Year	2001	2006	2011	2016	2021	2026	2031
Population	684	774	860	940	1,013	1,076	1,130

Generally, water demand increases as living standards rise, and the upper limit is considered to be 200 lcd according to the present level in developed countries. As the growth in demand is affected greatly by social and economic factors and changes in life style, long-term forecasting is difficult.

In this case, therefore, future per capita consumptions are assumed from growth in per capita consumptions as examined in the JICA Master Plan Study (growth of 2.5%/year due to the rise of living standards and growth of 0.37 liter/year due to the introduction of flush toilets) as follows:

(Unit: lcd)

Year	2001	2006	2011	2016	2021	2026	2031
Per capita consumption	120.7	138.6	158.6	181.4	200.0	200.0	200.0

When demand is predicted from those per capita consumptions, the assumption of future population and a leakage ratio of 25%, the following tables are produced.

(Unit: Thousand m^3/d)

Year	2001	2006	2011	2016	2021	2026	2031
Water demand	110	143	182	227	270	287	301

(Unit: Thousand m^3/d)

Year	2001	2006	2011	2016	2021	2026	2031
Deficit	19.2	52.2	91.2	136.2	179.2	196.2	210.2
	0	16.8	55.8	100.8	143.8	160.8	174.8

Note: Upper figures are those when the two projects are realized out of the JICA Water Supply Development Plan; lower figures are those when all eight projects are completed.

This water demand greatly differs from the water demand for forming the Melamchi project earlier. The deficit for water supply capacity even in 2031 will be 210,000 m^3/d when the two projects in the JICA Water Supply Development Plan are executed and 175,000 m^3/d when all eight projects are implemented. The deficit for water supply capacity is estimated to be 234,000 m^3/d for the saturated population of 1.35 million.

As above-mentioned, if water demand is widely different from the purpose of making the Melamchi project would make the drastic review of the formation of the long-term water supply plan. Therefore, careful study is required.

2) Positioning of the water supply development plans in the period until realization of the Melamchi project

Until 2001, the target year for the realization of the Melamchi project, the first and second 5-year plans of the 15YCDP and the JICA Water Supply Development Plan including the Project are to be executed

(Other plans than the two systems of the Project, the execution has not yet been scheduled). To achieve the maximum possible effect with the limited funds from the long-term waterworks development plan, it is necessary to avoid as far as possible overlapping with the past investment by fully making use of the facilities made under the water supply development plan until 2001 even the Melamchi project is realized.

Of the targets of the long-term water supply development plan, about the securing of water quantity, the water supply capacity will reach 85,700 m^3/d in 1995 when the Project is completed thanks to the in-valley water source expansion project as proposed by the JICA Water Supply Development Plan. In addition, when the remaining six projects are completed, the water supply capacity will reach 126,200 m^3/d. Beyond 2001, with the completion of the Melamchi project, eternal service of these facilities will mean the following amounts of water that should be conveyed from outside the valley:

(Unit: Thousand m^3/d)

Year	2001	2006	2011	2016	2021	2026	2031
Quantity of water to be introduced	19.8	53.8	93.9	140.3	184.6	202.1	216.5
	0	17.3	57.5	103.8	148.1	165.6	180.0

Note: Upper figures are those when the two projects are realized out of the JICA Water Supply Development Plan; lower figures are those when all eight projects are completed.

The Melamchi project includes the construction of a tunnel 27 km in length and water intake from the Melamchi river at a rate of 2.6 m^3/s in the First Phase. To keep up with growth in demand thereafter, water will be conveyed subsequently in succession from the Yangiri (1.4 m^3/s) and Lark rivers (1.2 m^3/s), by constructing each additional tunnels.

In drawing up the Melamchi project, if the plan is made so that water supply facilities that will be constructed until the year 2001 are fully utilized, the conveyance amount from the Melamchi river in the first

Phase alone (224,600 m^3/d) should be sufficient to cope with the water demand up to 2031, the target year of the Melamchi project, when the above-mentioned necessary conveyance amount from outside the valley is considered. Thus the time of construction of water supply facilities for intake and conveying water from the Yangiri and Lark rivers in the next Phase may be delayed, and the proper scale and efficient investment in treatment plant, water transmission and distribution systems will be step by step conducted in accordance with newly water demand, to be the limit of needs from the new addition to water demand.

Since the expansion of water sources in the Yangiri and Lack rivers is expected to occur 40 years later at the earliest, the second Phase should be re-examined its reasonableness and necessity by reviewing the growth in population, per capita consumption and water demand.

3) Conformity with existing water distribution systems

In the first and second 5-year plans of the 15YCDP, the water distribution system in Greater Kathmandu will be prepared to cope with the 2001 water demand. However, with the completion of the water supply facilities excluding distribution facilities for conveying water from the Melamchi river, which is in the First Phase of the Melamchi project, the water supply capacity will be about 2.6 times of the capacity in 2001, and it can not be distributed enough water with the distribution systems up to 2001. That is, if the water quantity increases 2.6 times, the water pressure in distribution network will have to be raised about 5.8 times in order to distribute it through the same system. Gravity system from the existing distribution reservoir will not be able to cover water demand. In the case of booster pump system, an increase in leakage and bursting of distribution pipes may occur. Therefore, the following plans for the distribution system after completion of the Melamchi project have to be studied.

a) To replace the existing distribution pipes with the larger pipes or to increase the new distribution pipes in order to cope with the increase in the water demand.

b) To divide the water distribution area into subareas of suitable scale depending on the water demand distribution. To transmit treated water from the new treatment plant under the Melamchi project to the new or existing distribution reservoir in each water distribution area; and then to be distributed from these reservoirs using the existing distribution network.

The above plan of a) necessitates new piping work throughout Greater Kathmandu, a long and very expensive task as it involves great changes in the distribution system by the year 2001. On the other hand, b) makes effective use of the water distribution system developed before 2001. Although a land acquisition for the new distribution reservoir will have to be secured, the work will be relatively easy and water pressure in the water supply area can be made more uniform.

Thus the water distribution system after the completion of the Melamchi project should be based on b) above.

4.2.3 Water Supply facilities plan

(1) Target year for the Project

The Project includes the two projects in Stage 1 of the eight projects proposed in the JICA Water Supply Development Plan. Besides the Project, the water supply development plan for Greater Kathmandu until 2001 includes Stage 2 and Stage 3 of the JICA Water Supply Development Plan, plus the first 5-year plan (1991 to 1995) and the second 5-year plan (1996 to 2001) of 15YCDP. When these plans are executed, the thorough adjustment of the competing items will be required. Thus with the understanding that the Project is just a stage of the JICA Water Supply Development Plan with the target year of 2001, the Project has been drawn up with a target year of 1995.

(2) Water quantity plan

1) Planned water supply amount

The maximum water supply amount in 1989 was 62,800 m^3/d. Of this, 22,500 m^3/d was groundwater, accounting for 35.8%. The JICA Master Plan Study proposes that, in order to use the existing groundwater sources permanently, the available groundwater pumpage should be limited to 15,600 m^3/d. This means 14,500 m^3/d in terms of water supply quantity. Therefore, if groundwater is limited, as proposed at the condition of water supply in 1989, it already causes about 8,000 m^3/d short. Unless new water sources are developed, the shortage will have come to 30,900 m^3/d in 1995 when the Project reaches its planned completion rising to 71,400 m^3/d in the year 2001. In the Project, the target of water supply amount is to cope with at least the water demand (85,700 m^3/d) in 1995.

The planned water supply amount of the Project is based on the planned water supply amount of each water supply system, which was determined in consideration of the demand distribution, the conditions of water distribution system and water source capacity of the each system in the JICA Water Supply Development Plan.

The water supply capacity and water demand of the each water supply system in 1995 and 2001 are shown in Table 4.2.2 and Table 4.2.3, respectively. The planned water supply capacity is, therefore, 26,500 m^3/d from the Mahankal Chaur project and 22,100 m^3/d from the Bansbari project.

Table 4.2.2 WATER DEMAND AND PLANNED WATER SUPPLY AMOUNT IN 1995

(Unit: m^3/d)

System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sundarijal												
Demand	13,400	13,900	15,200	16,300	17,000	17,500	17,600	17,500	17,200	16,300	14,800	13,600
Supply amount	18,000	18,000	18,000	18,000	18,000	17,600	17,600	17,500	17,200	16,300	14,800	13,600
Balance	4,600	4,100	2,800	1,700	1,000	100	0	0	0	0	0	0
Mahankal Chaur												
Demand	18,700	19,500	21,300	22,800	23,800	24,400	24,600	24,500	24,000	22,700	20,700	19,100
Supply amount	19,100	14,900	15,400	19,400	22,000	24,100	24,600	24,500	24,000	22,700	20,700	20,200
- surface water	19,100	14,900	8,200	8,200	8,200	12,400	24,600	24,500	24,000	22,700	20,700	20,200
- groundwater	0	0	7,200	11,200	13,800	11,700	0	0	0	0	0	0
Balance	400	-4,600	-5,900	-3,400	-1,800	-300	0	0	0	0	0	1,100
Bansbari												
Demand	15,500	16,200	17,700	18,900	19,700	20,300	20,400	20,300	19,900	18,800	17,100	15,800
Supply amount	5,300	11,900	17,700	18,900	19,700	20,300	20,400	20,300	19,900	18,800	17,100	14,700
- surface water	5,300	5,300	5,300	5,300	5,300	5,300	20,400	20,300	19,900	18,800	17,100	14,700
- groundwater	0	6,600	12,400	13,600	14,400	15,000	0	0	0	0	0	0
Balance	-10,200	-4,300	0	0	0	0	0	0	0	0	0	-1,100
Balaju												
Demand	6,400	6,700	7,300	7,800	8,100	8,300	8,400	8,400	8,200	7,800	7,100	6,500
Supply amount	8,100	8,400	8,400	8,400	8,400	8,400	8,400	8,400	8,200	7,800	7,100	6,500
Balance	1,700	1,700	1,100	600	300	100	0	0	0	0	0	0
Shaibhu												
Demand	11,200	11,600	12,700	13,600	14,200	14,600	14,700	14,700	14,300	13,600	12,400	11,400
Supply amount	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,700	14,300	13,600	12,400	11,400
Balance	3,500	3,100	2,000	1,100	500	100	0	0	0	0	0	0
TOTAL												
Demand	65,200	67,900	74,200	79,400	82,800	85,100	85,700	85,400	83,600	79,200	72,100	66,400
Supply amount	65,200	67,900	74,200	79,400	82,800	85,100	85,700	85,400	83,600	79,200	72,100	66,400
Deficit	-10,200	-8,900	-5,900	-3,400	-1,800	-300	0	0	0	0	0	-1,100
Surplus	10,200	8,900	5,900	3,400	1,800	300	0	0	0	0	0	1,100

Table 4.2.3 WATER DEMAND AND PLANNED WATER SUPPLY AMOUNT IN 2001

(Unit: m^3/d)

System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sundarijal												
Demand	13,400	13,900	15,200	16,300	17,000	17,500	17,600	17,500	17,200	16,300	14,800	13,600
Supply amount	18,000	18,000	18,000	18,000	18,000	17,600	17,600	17,600	17,600	17,600	14,800	13,600
Balance	4,600	4,100	2,800	1,700	1,000	100	0	100	400	1,300	0	0
Mahankal Chaur												
Demand	18,700	18,500	21,200	22,800	23,800	24,400	24,600	24,500	23,900	22,700	20,700	19,100
Supply amount	19,100	14,900	20,800	22,800	26,500	25,400	24,600	24,600	24,600	22,700	20,700	20,200
- Surface water	19,100	14,900	8,200	8,200	8,200	12,400	24,600	24,600	24,600	22,700	20,700	20,200
- groundwater	0	0	12,600	14,600	18,300	13,000	0	0	0	0	0	0
Balance	400	-4,600	-400	0	2,700	1,000	0	100	700	0	0	1,100
Bansbari												
Demand	15,500	16,200	17,700	18,900	19,700	20,300	20,400	20,300	19,900	18,800	17,200	15,800
Supply amount	5,300	10,100	17,700	21,400	22,100	21,700	20,400	20,400	20,400	18,800	17,200	14,700
- surface water	5,300	5,300	5,300	5,300	5,300	5,300	20,400	20,400	20,400	18,800	17,200	14,700
- groundwater	0	4,800	12,400	16,100	16,800	16,400	0	0	0	0	0	0
Balance	-10,200	-6,100	0	2,500	2,400	1,400	0	100	500	0	0	-1,100
Balaju/Lambagar												
Demand	13,700	14,300	15,600	16,700	17,400	17,900	18,000	17,900	17,500	16,600	15,100	14,000
Supply amount	13,700	14,200	13,400	12,600	11,700	15,100	18,000	17,500	17,400	16,600	15,100	14,000
- surface water												
Balaju	8,400	8,400	8,400	8,400	8,400	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Lambagar	5,300	5,800	5,000	4,200	3,300	6,700	9,000	9,000	9,000	8,200	6,700	5,600
- groundwater	0	0	0	0	0	0	600	100	0	0	0	0
Balance	0	-100	-2,200	-4,100	-5,700	-2,800	0	-400	-100	0	0	0
Shaibhu												
Demand	15,500	16,200	17,700	18,900	19,800	20,300	20,400	20,300	19,900	18,800	17,200	15,800
Supply amount	17,500	17,500	17,500	20,400	20,400	20,400	20,400	20,400	17,800	17,500	17,200	15,800
- surface water	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,200	15,800
- groundwater	0	0	0	2,900	2,900	2,900	2,900	2,900	300	0	0	0
Balance	2,000	1,300	-200	1,500	600	100	0	100	-2,100	-1,300	0	0
Manohara												
Demand	9,600	9,900	10,900	11,700	12,200	12,500	12,600	12,600	12,300	11,700	10,600	9,800
Supply amount	10,500	12,600	10,900	10,900	11,700	12,600	12,600	12,600	12,600	11,700	10,600	9,800
Balance	900	2,700	0	-800	-500	100	0	0	300	0	0	0
Balkhu												
Demand	9,600	9,900	10,900	11,700	12,200	12,500	12,600	12,600	12,300	11,700	10,600	9,800
Supply amount	10,500	12,600	10,900	10,900	11,700	12,600	12,600	12,600	12,600	11,700	10,600	9,800
Balance	900	2,700	0	-800	-500	100	0	0	300	0	0	0
TOTAL												
Demand	96,000	99,900	109,200	117,000	122,100	125,400	126,200	125,700	123,000	116,600	106,200	97,900
Supply amount	96,000	99,900	109,200	117,000	122,100	125,400	126,200	125,700	123,000	116,600	106,200	97,900
Deficit	-10,200	-10,800	-3,000	-5,700	-6,700	-2,800	0	-400	-2,200	-1,300	0	-1,100
Surplus	10,200	10,800	3,000	5,700	6,700	2,800	0	400	2,200	1,300	0	1,100

2) Water source plan

(a) Summary

According to the 1973 Master Plan, the water sources to cope with increasing water demand should come from the development of springs in the southern part and groundwater in the northern part of the valley until 1996, and there after the use of water from outside the valley should meet the demand. The development of the springs in the southern part and the groundwater in the northern part of the valley was brought to completion in 1987.

Although the target groundwater pumpage capacity of the 37 wells constructed was to be 40,000 m^3/d, the JICA Master Plan Study stated that the groundwater in the Kathmandu valley was restricted and therefore hardly recharged and should be abstracted no more than 15,600 m^3/d in order to enable the eternal service of this groundwater.

The plan of introducing surface water from outside the valley for 1997 and on is likely to be delayed for reasons of the progress schedule and financing, although the feasibility study is already conducted (1991 to 1992) with the assistance of the IDA. The situation being such, UWSSRP to develop water sources of 32,000 m^3/d through 1) the improvement and rehabilitation of the existing wells, 2) the improvement of the existing surface water sources, 3) the conjunctive use of available surface water from the Bagmati river in the wet season and groundwater from six wells to be newly constructed.

This UWSSRP water source plan is an emergency improvement and development one to cover the period until the realization of the Melamchi project. In other words, when the conveyance plan from outside the valley, the existing water sources inside the valley will be abandoned and the supply will depend solely on surface water from outside the valley. In particular about groundwater, it will be abstracted by improving the existing wells and constructing six new wells until the realization of the Melamchi project. Depending on management of groundwater in the future, it is possible that the groundwater may dry up before the realization of the Melamchi project.

On the other hand, the water source plan in the JICA Water Supply Development Plan is set forth as following providing an existing groundwater and existing surface water are used permanently and new surface water source are developed:

a) The pumping rate of the existing groundwater is limited to 15,600 m^3/d according to the recommendations of the JICA Master Plan Study, and this groundwater will take an important role in the long-term water supply plan.

b) The intake facilities and treatment plants for the existing surface water sources will be improved and take an important role in the long-term water supply plan.

c) The potentials of all rivers in the valley to supply water have been examined in the JICA Master Plan Study for the development of surface water sources within the valley. In all the rivers, the discharge is generally concentrated in the rainy season and the available intake amount is restricted in the dry season. Therefore, the required water supply will be secured by conjunctive use of the finite groundwater and the surface water which is limited in the dry season.

The water source plan until the realization of the Melamchi project to take an important role in the long-term water supply plan should be formed with a fully adjustment between UWSSRP and the JICA Water Supply Development Plan on the basis of the following basic ideas:

a) A pumpage of more than 45,400 m^3/d from the existing groundwater sources should be secured under the improvement plan of the UWSSRP. The existing groundwater sources, however, should only be put to use as a supplement to surface water in the dry season which will have a high level of monthly variation. In other words, groundwater shall be used permanently water source by limiting the annual average pumpage to 15,600 m^3/d.

b) The existing surface water sources (Balaju, Sundarijal, Shaibhu systems) will become important water sources in the long-term water supply plan by improving and reconstructing the intake facilities and treatment plants.

c) Surface water sources (Mahankal Chaur and Bansbari systems) that are to be used conjunctively with the existing groundwater sources and the available surface water sources (Manohara and Balkhu systems) available even in the dry season should be developed.

Based on this basic policy, the water source plan of the Project is studied in more detail below:

(b) Groundwater sources

In the Project the existing groundwater sources will be used solely as a supplement in the dry season when surface water runs short. The existing state of a total of 27 wells, including the Gokarna well field (5 wells), the Manohara well field (6 wells), and the Dhobi Khola well field (8 wells) plus the Bansbari well field of the Bansbari system, and the possibility of their permanent use are examined.

Based on the results of the field survey and the existing data, the groundwater pumpage and groundwater levels, are shown in Table 4.2.4.

a) Pumpage

The measurement of pumpage were made by using the water mill-type flow meters attached to the discharge pipe and ultrasonic flow meter. Many of the water mill-type flow meters were faulty or did not rotate smoothly, but the measured values were larger by about 12% than those made by the ultrasonic flow meter as a result.

The pumpage values obtained so far were taken with the mill-type meters, and presume that this values are larger than the actual values. Even considering this fact, the present pumpage reduces 44% to 76% (average 53%) of rated pumpage capacity in the Bansbari field, 26% to 67% (average 40%) in the Gokarna well field, 39% to 54% (average 45%) in the Manohara well field, and 24% to 54% (average 35%) in the Dhobi Khola well field. This is presumed to come for the following reasons:

- Shortage of the available pumpage due to insufficient logging and bad positioning of screen when the wells were constructed.
- Reduced collecting function due to poor filling of the filter material in the screen.
- Insufficient water level for proper pump suction due to a sudden lowering in water level.
- Reduced pumpage as a result of an increase in discharge head due to lowering of the groundwater level.
- Greater head loss of water conveyance pipes as a result of restrictions in water flow rate function due to the complex piping and corrosion of the pipes, etc.

Although it is difficult to conceive such large decreases in pumpage in view of performance figures for the existing pumps and the water conveyance piping system, such decreases may have occurred due to a combination of these causes.

Table 4.2.4 FLOW RATE OF NWSC PRODUCTION WELLS

Well Field	Design			Present Condition			
	Discharge (m^3/min)	S.W.L (GL-m)	P.W.L (GL-m)	Discharge*1 (m^3/min)	Discharge*2 (m^3/min)	S.W.L (GL-m)	P.W.L*3 (GL-m)
Bansbari Well Field							
BB0	1.479	48.30	68.00	1.200	1.090		
BB2	1.264	32.40	64.40	-	0.957		41.20
BB3	3.055	1.40	14.90	2.400	1.718		31.60
BB4	3.055	0.60	9.60	2.200	1.258		30.90
BB5	3.055	1.80	9.60	2.300	1.489	29.30*3	
BB6	3.055	2.00	19.00	2.300	1.634		38.00
BB7	3.472	+2.00	6.10	2.000	1.599		27.60
BB8	3.055	6.00	7.00	Not in operation		32.60*3	
Dhobi Khola Well Field							
DK3	1.521	1.00	20.70	0.376	0.415		
DK4	1.521	5.80	12.60	0.806	0.441		
DK5	1.521	29.60	34.40	-	0.819	45.00*3	
DK6	0.799	2.00	16.00	0.570	0.188		19.70
Gokarna Well Field							
GK1	2.014	8.60	21.60	1.900	1.350		
GK2	2.014	6.10	27.20	-	0.541		39.60
GK3	2.014	10.00	32.60	1.200	0.523		55.60
GK4	2.014	11.30	44.40	Not in operation		17.40	
GK5	1.521	20.40	37.30	Not in operation		30.70	
Manohara Well Field							
MH2	2.812	17.50	32.60	2.000	1.277	43.70*3	50.30
MH3	2.812	14.40	29.60	2.300	1.193		
MH4	2.812	5.00	17.60	2.600	1.519		
MH5	2.812	1.25	10.27	Not in operation		24.75	
MH6	2.812	+1.20	7.70	Not in operation			
MH7	2.812	2.40	12.00	1.400	1.100	28.40*3	
Total	53.301				19.212		

Note S.W.L.: Static water level
P.W.L.: Pumping water level
*1: Discharge measured by mill-type flow meter installed in each well
*2: Discharge measured by ultrasonic flow meter
*3: Water level measured on February 1989 (JICA Master Plan Study)

b) Groundwater Level

Table 4.2.5 shows the changes in the groundwater levels of the Gokarna, Manohara, Dhobi Khola, and Bansbari well fields. Because of the poor management of the charging pipes used to measure the water level, it was impossible to measure the water level in wells during pumping in this field survey, and therefore the measurement of the water levels was made at wells where pumps had been removed for repair or maintenance inspections. Although it is difficult to conclude having such a few data, the tendency of the lowering of groundwater level becomes moderately. It is considered that pumping operation is carrying out closely to the optimum pumpage and the proper groundwater management is now achieved.

Table 4.2.5 STATIC GROUNDWATER LEVEL TRENDS

(Unit: GL-m)

Year/Month		BB5	DK1	DK5	GK4	GK5	MH5	MH6
1984	May	1.75	29.38					
1985	May			29.60	11.30	20.40	1.25	+1.20
1988	Feb					25.20		
	Mar					23.92		
1989	Jan					27.00		7.15
	Feb	17.77	42.24					
	Mar	17.71	42.35			27.30		7.86
	Nov	29.29	42.15	45.00		31.28		
1990	Apr		42.20					
1991	Mar				17.40	30.70	24.75	

A survey was conducted for the purpose of comparing dynamic water level during pumping, the recovery in water level when pumping stops, and the lowering water level when pumping resumes at the DK5 well. The level in DK1 about 100 m distant was measured instead of the water level in DK5 well impossible to measure. Table 4.2.6 shows the results of the measurement.

A recovery of only about 2 cm was recorded when the pumping was stopped for about an hour. After an hours and half of the resumption of pumping, the water level was not lower. The water level in DK1 was not lowered and stabilized since 1989 year; as shown on Table 4.2.6.

Table 4.2.6 RESULTS OF PUMPING TEST ON DK5 WELL

Operation (DK5, Q=1,200 l/min)		No operation (DK5, Q= 0 l/min)		Operation (DK5, Q=1,200 l/min)	
Time	Water level* (GL-m)	Time	Water level* (GL-m)	Time	Water level* (GL-m)
13:30	41.72	14:30	41.83	15:30	41.80
35	41.73	31	41.82	31	41.80
40	41.74	32	41.82	32	41.80
45	41.76	33	41.82	33	41.80
50	41.77	34	41.82	34	41.80
55	41.79	35	41.82	35	41.80
14:00	41.80	36	41.82	36	41.80
05	41.80	37	41.82	37	41.80
10	41.81	38	41.82	38	41.80
15	41.82	39	41.82	39	41.80
20	41.73	40	41.82	40	41.80
25	41.73	42	41.82	42	41.80
30	41.73	44	41.82	44	41.80
		46	41.82	46	41.80
		48	41.82	48	41.80
		50	41.82	50	41.80
		55	41.82	55	41.80
		15:00	41.81	16:00	41.80
		05	41.80	05	41.80
		10	41.80	10	41.80
		15	41.80	15	41.80
		20	41.80	20	41.80
		25	41.80	25	41.80
		30	41.80	30	41.80
				40	41.80
				50	41.80
				17:00	41.80

Note *: Water level in DK1 well
Distance between DK1 and DK5 well is about 100 m.

c) Pumping plan

In 1991 the wells are being operated for 24 hours and the average pumpage is 13,480 m3/d for the Mahankal Chaur system - 2,680 m3/d for Dhobi Khola well field, 7,330 m3/d for Manohara well field and 3,470 m3/d for Gokarna well field - and 12,460 m3/d for Bansbari well field of the Bansbari system. At this pumpage, the water levels are relatively stable and it seems that groundwater management at close to the proper pumpage has been achieved because of the reduction in pumping capacity. As proposed in the JICA Master Plan Study, the optimum pumpage of 6,100 m^3/d for the Gokarna, Manohara and Dhobi Khola well fields and 6,900 m^3/d for the Bansbari well field show a high safety for the permanent use of the groundwater.

The daily maximum intake amount, the daily maximum pumpage and annual average pumpage are as shown below for the Project. The daily average pumpage is less than the optimum pumpage proposed by the JICA Master Plan Study, and the permanent use of groundwater will be possible by performing the proper groundwater management.

(Unit: m^3/d)

Project	Max. intake per day	Max. abstraction per day	Average abstraction per day over a year	Optimum abstraction
Mahankal Chaur	19,100	22,200	5,980	6,100
Bansbari	17,600	20,400	6,740	6,900
Total	36,700	42,600	12,720	13,000

The daily maximum pumpage in 1991 is only 13,480 m^3/d for the Mahankal Chaur system and 12,460 m^3/d for the Bansbari system. To secure the daily maximum pumpage required for the Project, it is necessary to improve the existing wells.

d) Proposal for the improvement of existing wells

The planning and construction supervision for improving the function of and augmenting for the groundwater intake facilities (wells, pumps, water conveyance pipeline) is to be undertaken by a German consultant (GWE) according to the first 5-year plan of the 15YCDP.

Since groundwater forms an important water source for the Project and the proper ground water management is necessary to permanently play good enough effectiveness of the Project, the following proposal to fully reflect the Project is hereby made.

- Since the complete construction of well is very important in order to have superior function, a contractor who has a competent skill should be employed.

- Since the main aquifers of the existing groundwater can hardly recharge, in the future it is expected that the groundwater level will lower, though gradually. The casing diameter of existing well below the position where a well pump is set is shorter than that above, so that the pump cannot be set down to cope with lowering groundwater levels. It is thus desirable to design wells so that the pump can be lowered to cope with falling groundwater levels to some extent. If it is impossible because of the wells's structure, it is desirable to cope with the problem in accordance with the pump specifications.

- Because groundwater is to be abstracted in the concentrated period of 3 to 4 months during the dry season, the pump should have the capacity to abstract the daily maximum pumpage. However, a pump with too much allowance should not be used. The allowance should be about 20% or less. The pumping capacity of the wells are designed as shown below according to the characteristics of the wells.

Mahankal Chaur project	
Gokarna well field	5.2 m^3/min
Manohara well field	10.0 m^3/min
Dhobi Khola well field	3.0 m^3/min
Total	18.2 m^3/min
Bansbari project	
Bansbari well field	17.0 m^3/min

The plan of improving the wells devised from the above-mentioned standard is set forth in Table 4.2.7.

- For proper groundwater management, the monitoring of pumping rate and groundwater level is important. Therefore, thefacilities with durable and simple measuring instruments shold be equipped.

- The machine for the cleaning of wells should be provided and cleaning should be performed periodically.

Table 4.2.7 PROPOSAL FOR WELL IMPROVEMENT AND REHABILITATION PLAN

Well No.	Pumping capacity (m^3/min)	Head (m)	Cost (Thousand NRs)
Mahankal Chaur project			
DK2	0.75	50	930
DK3	0.75	50	930
DK5	1.5	50	1,040
GK1	2.0	40	1,150
GK2	1.0	40	1,040
GK3	1.0	40	1,040
GK4	0.6	60	930
GK5	0.6	60	930
MH2	2.0	60	1,270
MH3	2.0	60	1,270
MH4	2.4	50	1,270
MH5	1.8	50	1,150
MH7	1.8	70	1,270
Sub-Total	18.2		14,220
Bansbari project			
BB0	1.5	70	1,270
BB1	2.0	80	5,600
BB2	1.5	50	1,270
BB3	2.0	100	1,500
BB4	2.0	100	1,500
BB5	2.0	100	1,500
BB6	2.0	100	1,500
BB7	2.0	100	1,500
BB8	2.0	100	1,500
Sub-Total	17.0		17,140
TOTAL	35.2		31,360

(c) Surface water sources

Although in the Project the existing groundwater sources are used to supplement the shortage of surface water in the dry season, it is necessary to develop surface water sources to be able to reduce the burden as much as possible on the groundwater even in the dry season.

a) Mahankal Chaur project

The available surface water sources for this project are the Dhobi Khola and Bagmati river.

- Dhobi Khola

Fig. 4.2.3 shows a water balance model for the Dhobi Khola. Table 4.2.8 shows the monthly distribution of surplus river water at the proposed intake site (W202) in the JICA Water Supply Development Plan. Also the available river water with 80% dependability is shown in Table 4.2.9. The results of flow measurement during this field survey conducted in March showed 0.057 m^3/s, about the same as the available intake amount of 0.05 m^3/d in March at the same point. However, because there are paddy fields upstream of this intake site and the possibility of contamination from agricultural chemicals, fertilizers, and so forth must be considered and because the environment of the intake site near the ring road is unfavorable, the intake location is considered unsuitable. If the intake site is moved upstream, the available river water in the dry season will be limited because water is mainly for irrigation. Worse still, securing a power source would be a problem as there is no available power line for the intake pump, which means the necessity for branching from the existing power line along the road. This involves some distance of power distribution and high costs for land acquisition and construction. Thus the river is unsuitable as a source of water.

Fig. 4.2.3 WATER BALANCE STUDY MODEL

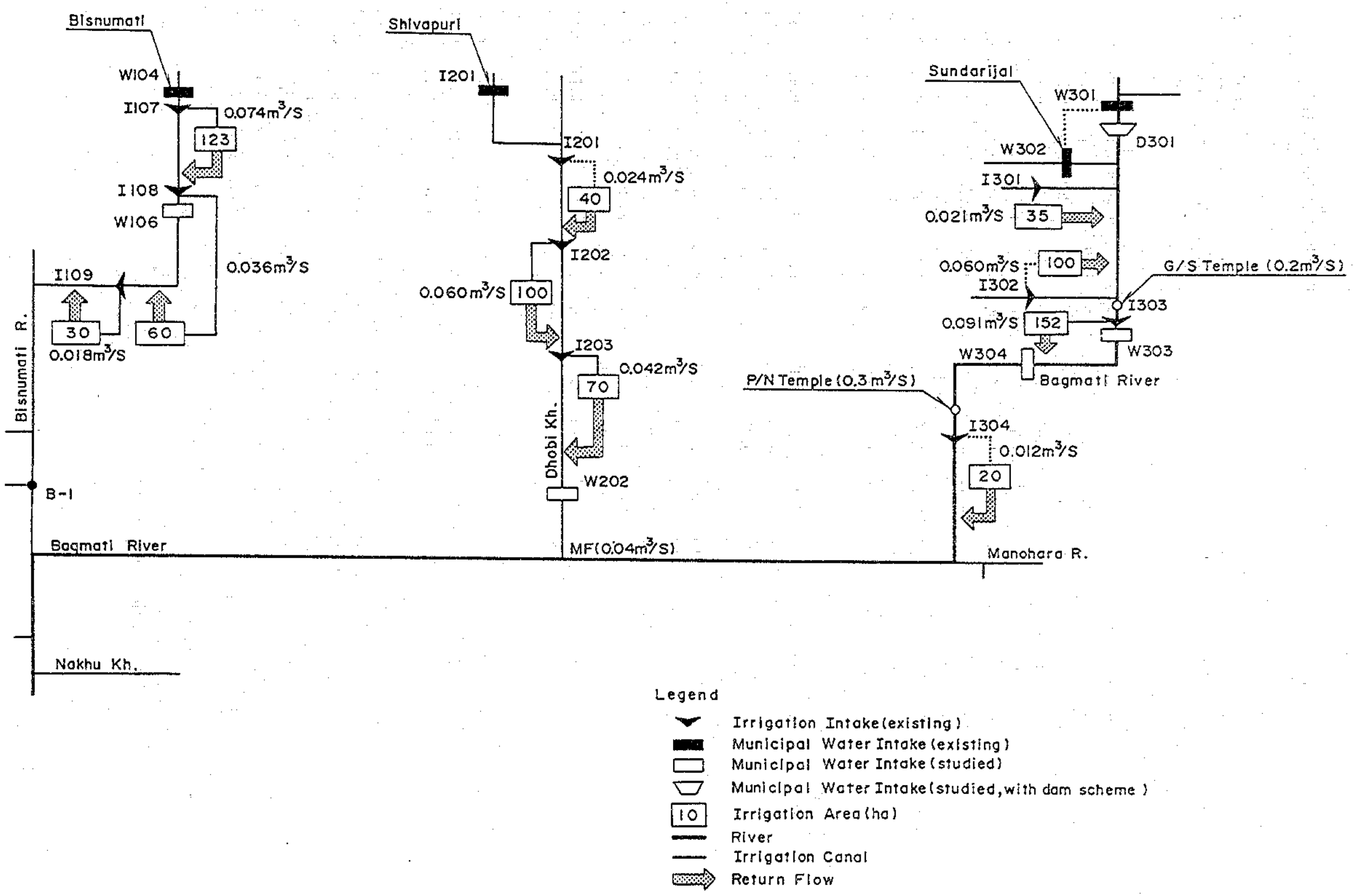


Table 4.2.8 MONTHLY DISTRIBUTION OF SURPLUS RIVER WATER

(Unit: m^3/s)

Balance Points	Time (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dhobi Khola													
W202	50	0.11	0.08	0.07	0.06	0.07	0.29	1.58	2.23	1.44	0.46	0.28	0.15
	55	0.11	0.08	0.06	0.06	0.06	0.24	1.46	2.09	1.36	0.42	0.26	0.14
	60	0.10	0.07	0.06	0.06	0.06	0.20	1.37	1.99	1.26	0.38	0.24	0.13
	65	0.10	0.07	0.60	0.06	0.06	0.16	1.25	1.90	1.19	0.34	0.23	0.13
	70	0.09	0.06	0.06	0.05	0.05	0.11	1.16	1.81	1.08	0.30	0.20	0.12
	75	0.08	0.06	0.06	0.05	0.05	0.09	1.09	1.65	1.00	0.28	0.18	0.11
	80	0.08	0.06	0.05	0.05	0.04	0.07	0.99	1.52	0.92	0.25	0.17	0.09
	85	0.08	0.06	0.05	0.04	0.04	0.06	0.86	1.40	0.82	0.22	0.14	0.09
	90	0.07	0.05	0.05	0.04	0.04	0.05	0.70	1.19	0.68	0.19	0.13	0.08
	95	0.06	0.05	0.04	0.04	0.04	0.04	0.48	1.10	0.48	0.16	0.11	0.08
	100	0.06	0.04	0.04	0.03	0.03	0.03	0.40	0.65	0.24	0.12	0.09	0.06
Bagmati river													
W301	50	0.24	0.18	0.08	0.07	0.11	1.06	4.31	6.05	3.97	1.47	0.69	0.37
	55	0.24	0.17	0.06	0.05	0.09	0.89	4.07	5.64	3.75	1.34	0.63	0.35
	60	0.22	0.15	0.05	0.02	0.06	0.72	3.77	5.39	3.56	1.25	0.59	0.33
	65	0.20	0.12	0.03	0.01	0.04	0.57	3.47	5.15	3.23	1.17	0.54	0.31
	70	0.18	0.11	0.03	0.00	0.01	0.35	3.17	4.85	3.11	1.02	0.48	0.26
	75	0.16	0.09	0.00	0.00	0.00	0.17	3.04	4.48	2.91	0.97	0.44	0.22
	80	0.13	0.08	0.00	0.00	0.00	0.05	2.74	4.25	2.61	0.87	0.39	0.20
	85	0.13	0.06	0.00	0.00	0.00	0.00	2.52	3.90	2.39	0.76	0.33	0.18
	90	0.11	0.04	0.00	0.00	0.00	0.00	2.12	3.38	2.07	0.65	0.29	0.16
	95	0.09	0.00	0.00	0.00	0.00	0.00	1.60	3.06	1.60	0.57	0.24	0.13
	100	0.05	0.00	0.00	0.00	0.00	0.00	0.00	1.99	0.87	0.40	0.16	0.09
Bisnumati Khola													
W106	50	0.03	0.01	0.00	0.00	0.01	0.07	0.73	1.05	0.65	0.16	0.12	0.05
	55	0.03	0.01	0.00	0.00	0.00	0.06	0.67	0.98	0.62	0.14	0.11	0.04
	60	0.03	0.01	0.00	0.00	0.00	0.03	0.62	0.92	0.57	0.11	0.10	0.04
	65	0.02	0.00	0.00	0.00	0.00	0.02	0.57	0.89	0.53	0.10	0.09	0.04
	70	0.02	0.00	0.00	0.00	0.00	0.00	0.51	0.83	0.48	0.08	0.08	0.03
	75	0.02	0.00	0.00	0.00	0.00	0.00	0.48	0.76	0.42	0.07	0.07	0.03
	80	0.02	0.00	0.00	0.00	0.00	0.00	0.42	0.68	0.38	0.06	0.06	0.03
	85	0.01	0.00	0.00	0.00	0.00	0.00	0.36	0.63	0.33	0.05	0.05	0.02
	90	0.01	0.00	0.00	0.00	0.00	0.00	0.28	0.53	0.27	0.04	0.04	0.02
	95	0.01	0.00	0.00	0.00	0.00	0.00	0.15	0.47	0.15	0.02	0.03	0.02
	100	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.05	0.01	0.02	0.01

Note Time: dependable time
Balance points are shown in Fig 4.2.3

Table 4.2.9 MONTHLY EXPLOITABLE WATER WITH 80% DEPENDABILITY

(Unit: m^3/s)

Balance Point	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dhobi Khola												
W202	0.08	0.06	0.05	0.05	0.04	0.07	0.99	1.52	0.92	0.25	0.17	0.09
Bagmati river												
W301	0.13	0.08	0.00	0.00	0.00	0.05	2.74	4.25	2.61	0.87	0.39	0.20
Bisnumati Khola												
W106	0.02	0.00	0.00	0.00	0.00	0.00	0.42	0.68	0.38	0.06	0.06	0.03

Note: Balancing points are shown in Fig. 4.2.3

- Bagmati river

Fig. 4.2.3 shows a water balance model of the Bagmati river. Table 4.2.8 shows the monthly distribution of surplus river water at point of W301. Also, the available river water with 80% dependability is shown in Table 4.2.9. Intake amount at the point of W301 which was adopted for this water balance analysis is the water for the Sundarijal power plant. According to the design specifications of the Sundarijal power station (Table 4.2.10), water is taken at a rate of 0.765 m^3/s at the time of maximum output and 0.38 m^3/s during the dry season, and the station has the guaranteed water right to this intake amount.

Flow measurement during this field survey showed that the water quantity needed for power generation with the operation of one generator and two generators, respectively, was 0.3 m^3/s and 0.56 m^3/s. The pattern of power generation is for two generators to operate for 5 hours in the morning and 4 hours at night, 9 hours in total, and for one generator to operate for the remaining hours, and the average water amount for power generation is 0.4 m^3/s as ordinary pattern. Consequently, although it is impossible to take newly from the Bagmati river in the dry season, the design lowest-level flow rate for power generation of 0.38 m^3/s can be taken. With an allowance of 10%, the exploitable water becomes 29,500 m^3/d (0.38 m^3/s x 86,400 x 0.9 = 29,500 m^3/d). Since 20,600 m^3/d is required for the existing Sundarijal treatment plant and 400 m^3/d for about 40 households near the Sundarijal treatment plant, 8,500 m^3/d can be supplied to the new treatment plant.

As a result of this study, the surface water for this project should come from tailrace from the Sundarijal power station (new) and the Bagmati river water (at a point 200 m upstream of the Sundarijal treatment plant) in combination.

Table 4.2.10 SPECIFICATION FOR SUNDARIJAL POWER STATION

Items	Description
1. Flow Rate at Maximum Output	$0.765\ m^3/s$
2. Power Generating Capacity	640 kW (340 kW x 2 Nos.)
3. Effective Head	212 m
4. Diameter of Penstock	450 mm
5. Length of Penstock	674 m
6. River Discharge in a Dry Season Shallmati Bagmati Nagmati	 90 l/s 90 l/s 200 l/s
7. Reservoir Capacity in Bagmati	$1,428\ m^3$ (Run-of-river type)
8. Canal Length Shallmati Nagmati Bagmati	 1,000 m 450 m Directly flowing into dam
9. Construction Year	1935

b) Bansbari project

The potential surface water sources for the development in this project are the Bisnumati Khola and two existing springs at Bisnumati and Shivapuri.

- Bisnumati Khola

Fig. 4.2.3 shows a water balance model for the Bisnumati river. The flow in March 1991 at the proposed intake site (W106) in the JICA Water Supply Development Plan was only $0.01\ m^3/s$. Though rainfall is expected in and after March, the basin of $3.7\ km^2$ is small and water taken for irrigation of $0.074\ m^3/s$ is large. Table 4.2.8 shows the monthly distribution of surplus river water at that point. The available intake amount with 80% dependability is shown in Table 4.2.9.

It can be seen that the planned intake amount can only be available during a three months period from July to September, and no intake will be possible for the remaining seven months except that a rate of about 0.06 m3/s may be taken in October and November. Worse still a problem exists in securing power, since there is no available power line for the intake pump causing problems similar to those about the Dhobi Khola intake site. Therefore, this river is unsuitable as a source of water supply.

- Existing Bisnumati and Shivapuri springs

The results of flow measurement in March 1991, indicated the inflow rates of 0.33 m^3/s and 0.67 m^3/s respectively of Bisnumati and Shivapuri intake sources, all of which was used as a source of water supply. The conditions in March 1991 were considered extremely drought judging from past rainfall data, but assuming the flow rate of the dry season allowing for a safety factor of 30%, the available flow rate of the springs in the dry season would be 6,100 m^3/d. Subtracting household supplies for residents along the water conveyance pipeline from these intake points (530 m^3/d), 5,500 m^3/d is the available intake water of the springs in the dry season. A breakdown of household supply for residents along the piping is as follows:

Metered connections (functioning)	
152 houses x 7.65 persons/house x 125 lcd =	145.4 m^3/d
Metered connections (non-functioning)	
44 houses x 7.65 persons/house x 125 lcd x 1.10 =	46.3 m^3/d
Non-metered connections	
43 houses x 7.65 persons/house x 125 lcd x 1.71 =	72.8 m^3/d
Total	264.5 m^3/d

With efficiency rate of 0.5:

264.5 $m^3/d \div 0.5 =$ 530 m^3/d

On the basis of this study, surface water sources for this project should be developed by the expansion and improvement of the existing Bisnumati and Shivapuri intakes.

(3) Water quality plan

1) Target of improved water quality

On the basis of the 1973 Master Plan, spring water in the southern part and groundwater in the northern part of the valley was developed with the aim of good quality water sources to satisfy the increasing water demand until 1996. While the springs in the southern part of the valley, which is a limestone height, were found to be extremely satisfactory, groundwater in the northern part produced from 37 wells in the four well fields was found to contain a high concentration of iron, manganese, and ammoniac nitrogen and was a low pH and high corrosive, as shown in 3.4.2 in the previous section.

At present, this groundwater is supplied without treatment, causing directly the problems of colored water due to the iron and manganese contents and secondary problems in the distribution network due to iron and the ammonia nitrogen. Chlorine, fed for sterilization, is consumed by these impurities, growing to the increase of bacteria in the network and turbidity and colored water resulting from the remains of their death. Further, bacteria reach the consumers and the water may contain pathogenic bacteria. The treatment plants for surface water were constructed in the 1960's, so they are already nearly 30 years old. Their functioning is paralyzed and high concentration of iron and turbid substance is contained in the water during the dry season, and problems similar to those with groundwater arise.

The aims of a waterworks are to supply safe, clean water to inhabitants, thus contributing to improved public hygiene and a living environment. To achieve this, it is necessary to prevent contamination at its sources, carry out proper water quality management at the treatment plant, and prevent inside and outside contamination of distribution network and service installations. If water quality control is not carried out properly, it becomes not only loose the purpose of water supply facilities, but also make a cause of spreading contagious and water-borne diseases. To achieve the basic aims of a waterworks, the improvement of water quality is necessary as follows:

a) Directly, to secure the sterilized faculty distribution network, etc., including the removal of iron and manganese contents and the sterilization of coliform bacilli and general bacteria.

b) Indirectly, to prevent secondary trouble with the distribution piping due to the existence of iron and ammonia nitrogen and prevent corrosion in the distribution piping by improving the corrosive water.

It is necessary to form a water improvement plan based on the above targets, with both the surface water and groundwater sources in the Project.

2) Improvement of groundwater quality

The supply of groundwater is 38,600 m^3/d at maximum in the JICA Water Supply Development Plan, equivalent to 30.6% of the maximum water supply amount and 10.3% of the annual water supply amount. Thus it is an important supplementary source for the shortage surface water sources in the dry season. At present, the groundwater is supplied without any treatment, so it causes problems in terms of water quality. Therefore, it is necessary to take up water quality improvement measures against iron, manganese, and ammonia nitrogen.

The removal of iron (dissolved iron) generally involves oxidizing the iron using dissolved oxygen or chlorine, treatment by coagulo-sedimentation and manganese sand filtration. Iron is easy to oxidize (Redox potential Eo = 0.2V) and 0.63 mg/l of chlorine oxidizes 1 mg/l of iron. Manganese removal treatment generally consists of manganese sand filtration in the presence of free chlorine (normally 0.6 to 1.0 mg/l). Chlorine at a concentration of 1.29 mg/l will oxidize 1 mg/l of manganese. Manganese does not oxidize easily and its redox potential is Eo = 0.6V.

Ammonia nitrogen in the water reacts with the chlorine fed for removal of iron and manganese (iron > ammonia nitrogen > manganese) and produces chloramine and unless chlorine in excess of the breakpoint (BP) is fed, no residual free chlorine remains. To ensure residual free chlorine for manganese removal, chlorine must be fed at least to the breakpoint (BP = 7.73N + 0.45 : N = concentration of ammonia nitrogen.

As ammonia nitrogen is not directly oxidized by dissolved oxygen, nitrification using nitro-bacteria of which is proliferated under the existence of dissolved oxygen is made. This is the biological treatment method of ammonia nitrogen. Although manganese is not oxidized in this biological treatment, iron is oxidized easily. The treatment methods of ammonia nitrogen include the following:

a) Ammonia stripping
b) Ion exchange
c) Zeolite treatment
d) Treatment with combined chlorine
e) Biological treatment

Treatment methods a), b) and c) above are expensive and difficult in operation and maintenance. They are not considered suitable for water treatment for waterworks. The method d) above needs high techniques in the operation control, requires a large amount of chlorine, results in high treatment cost, and may grow harmful tryphenyl methane gas if organic matter exists. The method e) includes the biological filtration method, the rotating disk method, and the honeycomb tubing method. These differ in the material to which the biological membrane is affixed, the method of bringing the biological membrane into contact with the raw water, and the method of air supply. Table 4.2.11 shows a comparative study of these three methods. The biological filtration method excels from the viewpoint of efficiency, economy, and easy and simple operation and maintenance.

While considering the above unit processes, seven plans for the improvement of groundwater quality were examined as shown in Appendix-6. After examining these plans, it was found that it is necessary for achieving the water quality improvement target to remove ammonia nitrogen by means of treatment with combined chlorine or biological filtration first, and after that to treat by coagulo-sedimentation and manganese sand filtration. Biological filtration is also suitable from the viewpoint of economy, treatment efficiency and ease of treatment, operation and maintenance.

Table 4.2.11 COMPARISON OF BIOLOGICAL TREATMENT METHODS

	Honeycomb Type	Rotating Disc Type	Biological Contact Filtration Type
Treatment Method	Honeycomb tube aggregates are placed in a treatment basin. Water is treated by contacting with the biological film on the aggregates. Circulating power is given by aeration.	A series of discs, 40% of which are submerged in a treatment basin, are slowly rotated. Water is treated by contacting with the biological film on the discs.	Particle filter media are packed in a treatment basin. Raw water is passed through the media by down-flow and treated by contacting with the biological film on the media. Air is always injected to activate the biological film.
System Composition	Treatment basin Honeycomb Circulating air injection unit Cleaning unit	Treatment basin Rotating disc Shelter for drive unit	Treatment basin Filter media Bearing material Water collecting unit Air injection unit Make-up water pump
Capacity	About 2 hours of rotation time	About 2 hours of rotation time	About 120 m/day of filtration velocity
Area Required	0.015-0.020 $m^2/(m^2/d)$	0.020-0.030 $m^2/(m^2/d)$	About 0.010 $m^2/(m^2/d)$
Depth of Treatment Basin	5 - 7 m	3 - 4 m	4 - 5 m
Head Loss	Almost zero	Almost zero	Almost zero, depending on filter media
Aerator	Required to circulate water	Not required	Required in A/L-2/1 to activate biological film
Washing Unit	Required in danger of plugging	Not required	Required at proper interval
Sludge Discharge Unit	Frequently required	Frequently required	Not required
Construction Cost* (million US$)	4.05	3.05	2.21
O/M Cost* (million NRs/year)	3.54	4.72	1.24

Note: *) Treatment capacity 19,100 m^3/d

(4) Treatment facilities plan

1) Treatment facility

The plan is for the conjunctive use of the existing groundwater sources and surface water sources that can be newly developed. It is necessary to have an optimum facility plan based on the characteristics of water quality and quantity. In this report, six plans as shown in Table 4.2.12 and Table 4.2.13, respectively for the Mahankal Chaur and Bansbari projects on the basis of the above mentioned water source conditions and water quality improvement plan were studied in view of long-term waterworks development plan. There are two cases of which is use of generated sodium hypochlorite and use of bleaching powder as oxidation and sterilizing agents for each of 6 plans. Therefore, total of 12 cases were studied.

The construction, operation, and maintenance costs for each facilities plan were compared, and the results are Table 4.2.14. The average value for groundwater in Mahankal Chaur project was assumed to be 4.0 mg/l of iron, 1.7 mg/l of ammonia nitrogen and 0.16 mg/l of manganese and a pH of 6.5. For the Bansbari project, it was iron: 2.2 mg/l; ammonia nitrogen: 2.2 mg/l; manganese: 0.05 mg/l; and a pH of 6.2. The average turbidity of raw surface water was assumed to be 30° in the rainy season and 10° in the dry season. The feeding of available chlorine for sterilization was 1.5 mg/l for groundwater, 2.5 mg/l for surface water in the rainy season, and 1.5 mg/l for surface water in the dry season. The groundwater pumpage in each facility plan is shown in the table below.

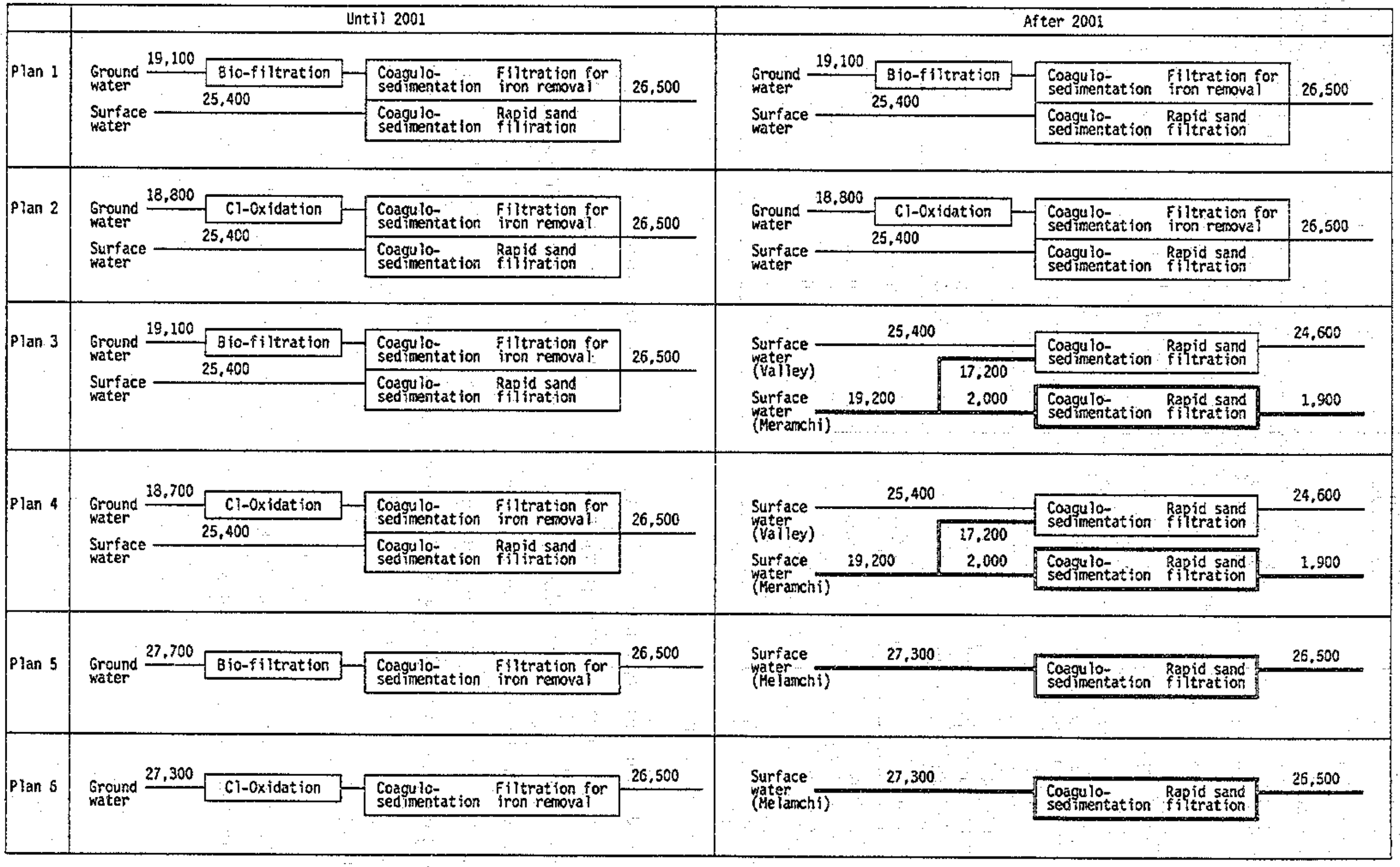
(Unit: m^3/d)

Plan	1994 to 2001	After 2001	Remarks
Mahankal Chaur project			
Plan 1	5,240	5,980	Annual average
Plan 2	5,160	5,890	
Plan 3	5,240	0	
Plan 4	5,160	0	
Plan 5	26,270	0	
Plan 6	25,880	0	
Bansbari project			
Plan 1	6,540	6,740	
Plan 2	6,430	6,430	
Plan 3	6,540	0	
Plan 4	6,430	0	
Plan 5	18,670	0	
Plan 6	18,350	0	

The pumpage according to Plans 1 to 4 warrant the groundwater can be made the water source permanently because they are within the optimum pumpage. However, the pumpage according to Plans 5 and 6 are 4.3 times as much as the optimum pumpage in the Mahankal Chaur project and 2.7 times as much as the one in the Bansbari project. Such excessive abstraction of groundwater, resulting in the impossibility of abstraction before 2001 and thus the necessity for finding new water sources providing as much as 49,800 m^3/d.

As the result of study as above-mentioned, Plan 1 is best for both the Mahankal Chaur and Bansbari projects.

Table 4.2.12 TREATMENT FACILITIES PLAN OF MAHANKAL CHAUR PROJECT



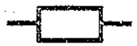
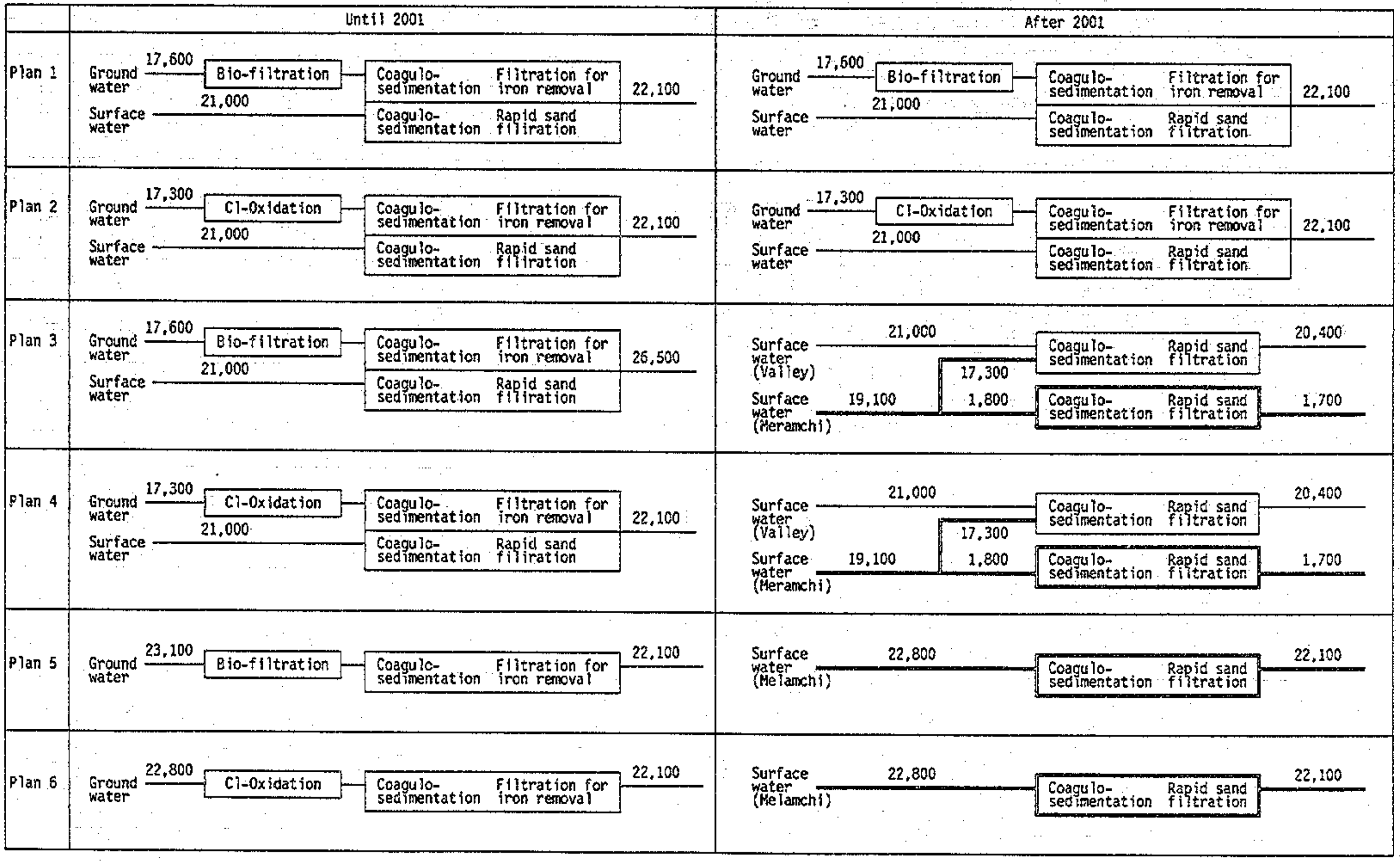
Note: Figure in the Table shows capacity of the facility (unit: m^3/d).  : Facility to be constructed after 2001

Table 4.2.13 TREATMENT FACILITIES PLAN OF BANSBARI PROJECT



Note: Figure in the Table shows capacity of the facility (unit: m^3/d). [bold box] : Facility to be constructed after 2001

Table 4.2.14 CONSTRUCTION, OPERATION AND MAINTENANCE COSTS

1. Mahankal Chaur project

Plan		Construction Cost (million US$)			Running Cost (million NRs/year)		Running Cost + Depreciation Expenditure (million NRs/year)	
		Until 2001	After 2001	Total	Until 2001	After 2001	Until 2001	After 2001
Plan 1	Sodium hypochlorite	15.1	0	15.1	8.59	8.59	25.39	25.39
	Bleaching powder	14.4	0	14.4	9.87	9.87	25.88	25.88
Plan 2	Sodium hypochlorite	14.9	0	14.9	10.79	10.79	27.38	27.38
	Bleaching powder	13.0	0	13.0	16.43	16.43	30.94	30.94
Plan 3	Sodium hypochlorite	15.1	19.1	34.2	8.59	7.39	25.39	45.49
	Bleaching powder	14.4	19.1	33.5	9.87	8.78	25.88	46.02
Plan 4	Sodium hypochlorite	14.9	19.1	34.0	10.79	7.65	27.38	45.53
	Bleaching powder	13.0	19.1	32.1	16.43	8.97	30.94	44.70
Plan 5	Sodium hypochlorite	10.0	27.4	37.4	13.18	6.93	24.38	48.53
	Bleaching powder	9.3	26.5	35.8	15.68	8.15	25.98	47.98
Plan 6	Sodium hypochlorite	14.4	27.4	41.8	19.42	6.99	35.49	53.52
	Bleaching powder	8.1	26.5	34.6	49.27	8.20	58.25	43.71

2. Bansbari project

Plan		Construction Cost (million US$)			Running Cost (million NRs/year)		Running Cost + Depreciation Expenditure (million NRs/year)	
		Until 2001	After 2001	Total	Until 2001	After 2001	Until 2001	After 2001
Plan 1	Sodium hypochlorite	11.0	0	11.0	7.55	7.52	19.77	19.77
	Bleaching powder	10.3	0	10.3	8.40	8.40	19.83	19.83
Plan 2	Sodium hypochlorite	10.4	0	10.4	8.14	8.14	19.74	19.74
	Bleaching powder	8.7	0	8.7	17.06	17.04	26.70	26.70
Plan 3	Sodium hypochlorite	11.0	16.6	27.5	7.52	6.21	19.73	36.86
	Bleaching powder	10.3	16.5	26.8	8.40	7.08	19.83	36.88
Plan 4	Sodium hypochlorite	10.4	16.6	27.0	8.14	6.42	19.74	36.46
	Bleaching powder	8.7	16.5	25.2	17.06	7.23	26.74	35.25
Plan 5	Sodium hypochlorite	8.5	23.0	31.5	12.09	5.79	21.54	40.80
	Bleaching powder	7.8	22.4	30.2	15.65	6.66	24.36	40.27
Plan 6	Sodium hypochlorite	12.1	23.0	35.1	16.49	5.98	30.01	45.07
	Bleaching powder	7.0	22.4	29.4	40.41	7.06	48.16	39.71

2) Coagulation

The coagulants which can be used at the treatment plants proposed in the Project are the following:

a) Solid aluminum sulfate (Alum) made in India.
b) Granulated poly aluminum chloride (PAC) made in Japan.
c) Ferrous chloride made in India.

	Alum (Available Al_2O_3 15%)	PAC (Available Al_2O_3 30%)	Ferrous (Available $FeCl_2$)
Unit price	14,500 NRs/ton	318,000 yen/ton	90,000 NRs/ton
Annual consumption	Mahankal Chaur 168.9 tons Bansbari 136.5 tons	Mahankal Chaur 29.3 tons Bansbari 23.6 tons	Mahankal Chaur 22.9 tons Bansbari 18.0 tons
Problem	Difficult to dissolve (necessary to crush into small pieces). Concentration of solution is not constant (feeding rate has to be decided every time). pH of raw water is low and highly corrosive, so feeding of alum makes pH even lower.	Foreign currency must be allotted for procurement, which will not be easy. Feeding operation is easy and cost of operation and maintenance is low.	Care must be exercised in handling as it shows high acidity when dissolved. $Ca(OH)_2$ feeding is needed to adjust pH, and coagulation involves a high skill. Iron may remain in treated water.
Annual cost	4,428,000 NRs	3,358,000 NRs	3,681,000 NRs

Note: 1 NRs = 5 yen

The deciding factor in the achievement of this Project's objectives is whether the treatment plants can be operated properly, fully demonstrating their functions. The most important point is proper operation of the coagulant feeding. Though there are anxiety to procure PAC, it is preferable to use PAC made in Japan, because feeding operation is accurate and easy, and the performance is excellent. Therefore, PAC is planned to be used in the Project. If solid aluminum sulfate made in India is used, it will be necessary to crush it in small pieces, separate out impurities and insoluble matter, and select the optimum feeding rate after making a jar test with the solution only, to make the optimum feeding operation.

3) Chlorination

To achieve a safe and sanitary water supply, the handling facility, operation, maintenance and economy of chlorine gas, bleaching powder, granulated sodium hypochlorite, and generated sodium hypochlorite were examined as regards chlorination, which is as important as the feeding operation of the coagulant.

	Chlorine gas	Bleaching powder	Granulated S.H.	Generated S.H.
Country of procurement	India	India	Japan	Made in place
Effective chlorine (%)	100	15	30	1
Unit price	26,000 NRs/ton	10,000 NRs/ton	194,000 yen/ton	7.7 NRs/Cl_2kg
Unit price per available chlorine (NRs/ton)	26,000	66,660	129,460	720
Depreciation (0.75%, 20 years)	0.030	0.004	0.004	0.086
Operation and maintenance cost	0.066	0.334	0.324	0.088 Electrolysis: 0.002 Replacement: 0.086
Total (NRs/ton/day)	0.096	0.338	0.328	0.174
Problems	Care must be exercised in handling as the gas is dangerous. O/M cost is low.	Difficult to dissolve and concentration of solution not constant. Dissolving operation is troublesome and feeding operation involves a high skill.	Although dissolving operation and feeding operation are easy, the allotment of foreign currency for imports will be difficult.	Feeding operation is easy,and O/M cost is low. However, electrode replacement which is required once every nine years presents problems in having the allotment of foreign currency.

Note: S.H. Sodium hypochlorite
1 NRs = 5 yen

As a result of studying the above-mentioned, it has been found as follows: Though this plan should rely on the use of generated sodium hypochlorite, since this has never been used in Kathmandu waterworks, of the two treatment plants the use of generated sodium hypochlorite should be planned in the Mahankal Chaur treatment plant and the use of bleaching powder should be planned in the Bansbari treatment plant.

4) Drainage and sludge disposal

Drainage and sludge is discharged from bio-filter, coagulo-sedimentation basin and rapid sand filter of the treatment plants proposed in the Project. The amount of the drainage and sludge is as follows:

	Mahankal Chaur	Bansbari
Drainage amount		
Bio-filter	414	378
Coagulo-sedimentation basin	234	176
Rapid sand filter	1,075	936
Total	1,723 m^3/d	1,490 m^3/d
Sludge amount	0.80 DS-t/d	0.66 DS-t/d
Turbidity of drainage	464 deg.	443 deg.

To dispose these drainage and sludge, following three methods can be considered:

	Dilution	Sun-dried	Dehydration
Methods of disposal	Sludge is diluted with drainage from rapid sand filter (turbidity of the diluted sludge should be less than 500 deg.) and drained to sewer or drainage canal.	Sludge is concentrated in a concentration tank and then sun-dried. The sludge cake with moisture rate of 70% is disposed.	Sludge is concentrated in a concentration tank and then formed into sludge cake with moisture rate of 60% by dehydrator.
Capacity required	-	70 kg/m^2/year (moisture rate of 70%)	6 kg/m^2/d (moisture rate of 60%)
Facility and area required	Drain pipe (VU pipe): φ200 mm x 350 m, φ200 mm x 150 m	Sun-dried bed: 1,050 m^2/bed x 5 beds (including 1 spare bed) 1,150 m^2/bed x 4 beds (including 1 spare bed) Area: 11,820 m^2	Dehydrator: 67.5 m^2 * x 2 sets 60.0 m^2 * x 2 sets *: dehydration area. Area: 400 m^2
Construction and land acquisition costs (million NRs)	Construction 1.16 Land - Total 1.16	Construction 1.76 Land 16.70 Total 18.46	Construction 76.12 Land 0.48 Total 76.60

As the drainage and sludge discharged from the treatment plants dose not contain contaminants, they should not cause environmental pollution. Therefore, dilution method is planned to dispose them in the Project.

5) Power supply to treatment plants

As a result of discussions with the Nepal Electricity Authority (NEA) and a field survey, the present situation for securing power supply for the new treatment plants and associated problems were following:

(a) Power supply to the Mahankal Chaur treatment plant

The electric power (500 KVA) to the existing Mahankal Chaur distribution reservoir is now supplied from New Chobar substation. As the distribution line involves many facilities (loads) and connected loads in excess of the service capacity. For this reason, power failures frequently occur due to accidents from overloading, deterioration of equipment, meteorological conditions (thunderstorms, etc.). Thus the power supply is not stable, and complaints from users have increased in number, and this distribution line becomes problematic. The following means may be considered for obtaining power supply to the treatment plants in this project:

a) To increase the capacity of the existing distribution line.

b) To apply some existing spare circuits in the substation and lay a new distribution line.

The means of a) involves extreme difficulty, so that the plan should rely on the means of b)

(b) Power supply to the Bansbari treatment plant.

The electric power (75 KVA) to the existing Bansbari distribution plant is now supplied from the Maharajganj transformer substation. Loads on this distribution line is relatively low and the line has some allowance of capacity. The power supply to the treatment plant in this project will come from the existing distribution line. However, if the stability of the power supply is considered, the reliability of the supply needs to be enhanced, for power failures have occurred due to thunderstorms, etc., and the deterioration of the equipment as in the case of Mahankal Chaur system.

6) Emergency power supply

With the power supply situation as described above it is extremely difficult to secure a stable supply for the treatment plants in this Project. Long power failure due to accidents in the distribution line will inevitably suspend the functions of these facilities. The following facilities must maintain a minimum operation so as not to impair the function of the treatment plants:

a) Bio-filter (alkali feeding equipment, blower unit)

b) Coagulant feeding equipment

c) Alkali feeding equipment

d) Sodium hypochlorite generator and feeding equipment

An emergency power source for the facilities will be required for continued operation of them in events of power failures. Ways to ensure an emergency power source during a power failures includes a two-circuit incoming system, a generator for emergencies, and an uninterrupted power supply equipment. A two-circuit incoming system would be difficult because the economic burden is too great considering the present situation of NEA. Spare generators for emergency use include diesel and gas turbine generators. Gas turbines have advantages over diesel generators, and the ratio of use has been increased. However, operation and maintenance are technically difficult and the price is higher than diesel generators. Uninterruptable power supply equipment is used for really critical loads not allowing even power failure even for a moment (for computers, etc.). Since the price is high and operation and maintenance become troublesome, they are not suitable for use in the Project.

Taking into consideration of condition above, diesel generators will be adopted as an emergency power supply source from the viewpoint of their general purpose use, operation, maintenance and price. The outline specification of the diesel generator are as shown below.

a)	Use	:	For emergency power supply
b)	Installation conditions	:	Temperature 0 °C to 30 °C, altitude less than 1500 m.
c)	Location	:	Indoor
d)	Output	:	300 KVA
e)	Voltage	:	400 V
f)	Cooling system	:	Radiator cooling
g)	Fuel	:	Heavy oil or light oil

4.2.4 Implementation and management plan

The implementation agency for this Project is the Nepal Water Supply Corporation (NWSC). Although the NWSC comes under the supervision of the Ministry of Housing and Physical Planning, but it is independent institutionally from government organizations, and the water supply works under its jurisdiction is managed by revenues from water charge. However, water rates in Nepal are still at a low level and the collection system of water charge is insufficient, so that revenues from water charge are insufficient. Thus, the accounts of the water supply works run in the red, resulting in a huge accumulated deficit for the NWSC (refer to Table 4.2.15).

For this condition, the NWSC, according to recommendation from the IDA, is now working on the improvement of the distribution system, overall installation of water meters, arrangement of a collection system, and the training of operation and management personnel under the UWSSRP based on the premise of a rise in water rates.

4.2.5 Necessity for technical cooperation

The existing treatment plants in Greater Kathmandu are Balaju (design capacity 10,900 m^3/d), Maharajganj (design capacity 2,400 m^3/d) and Sundarijal (design capacity 19,600 m^3/d), a total of three plants. All of them are of British-designed coagulo-sedimentation, rapid sand filtration systems, constructed in the 1960's. Besides these, there is sterilizing equipment at the five reservoirs.

The planned treatment plants in the Project are the Mahankal Chaur treatment plant (maximum capacity 27,300 m^3/d) and the Bansbari treatment plant (maximum capacity: 22,800 m^3/d). These treatment plants consist of bio-filter for ammonia nitrogen removal, coagulo-sedimentation basin to treat groundwater and surface water conjunctively, rapid sand filter or filter for iron removal and sterilizing equipment.

The coagulo-sedimentation and rapid sand filtration facilities are more simple and easier to handle compared with the existing ones, and the only problem they present is to secure operation and maintenance personnel. However, the sodium hypochlorite generator used for disinfection and the biological filtration will be the first case in Kathmandu waterworks.

To operate and maintain these facilities efficiently and to demonstrate the effectiveness of the Project over a long period of time, it is natural to give thorough guidance in the operation and maintenance at the time of completion. It is also necessary to dispatch Japanese experts for technical cooperation to train technical personnel and to improve their level of technology.

Although it is also necessary to make full use of the normal systems of training and bringing up engineers through the JICA training course, it is considered particularly effective for dispatched experts to transfer the proper technology for these facilities in the field.

4.2.6 Basic policy of cooperation for the Project

The effectiveness and practicality of the project and ability of the Government of Nepal to implement the Project have been confirmed through this study and the effects of the Project suits with those of grant aid assistance, so that it is judged that the Project as Grant Aid Assistance by the Government of Japan would be appropriate. With the Grant Aid Cooperation from the Government of Japan as a premise, a summary of the Project is examined and the basic design will be conducted below. The contents of the Project will be made more appropriate by altering parts of the Request through the study of the relations with the above-mentioned IDA/UNDP projects and the water supply facility plan.

Table 4.2.15 INCOME AND EXPENDITURE OF NWSC

(Unit: NRs)

Items	1988	1989
1. Income		
Revenue	24,288,802.10	26,968,203.64
Other income	9,616,101.28	11,510,046.16
Total	33,904,903.38	38,478,249.80
2. Expenditure		
Central expenses	7,108,652.34	8,709,302.10
Administrative expenses	9,461,953.69	30,757,158.41
Consumer's act expenses	2,510,146.72	-
Production expenses	3,539,980.67	13,017,665.71
Production tube well expenses	11,034,127.41	-
Distribution expenses	7,536,706.43	2,141,350.99
Sewerage maintenance expenses	742,142.53	-
Store sale	529,185.00	-
Interest expenditure	3,438,567.16	3,623,371.41
Depreciation expenditure	10,585,901.00	11,101,254.06
Provision for doubtful debts	-111,423.55	446,994.90
Total	56,375,939.40	69,796,097.58
3. Balance (1-2)	-22,471,036.02	-31,317,847.78
4. Loss up to last financial year	-103,215,569.97	-125,686,605.99
5. Loss taken to balance sheet (3+4)	-125,686,605.99	-157,004,453.77

Source: Information from Finance Department of NWSC.

4.3 Summary of the Project

In response to the Government of Nepal's request to the Government of Japan for Grant Aid Assistance in the implementation of Stages 1 and 2 of the JICA Water Supply Development Plan, two projects in Stage 1 relating to improving groundwater quality, which are judged by the Government of Japan as most urgent and having the highest priority, are studied in the following.

4.3.1 Mahankal Chaur project

This project is to develop water supply facilities with a maximum water supply capacity of 26,500 m^3/d by the conjunctive use with the surface water which is limited in the dry season and the finite groundwater sources. The surface water is to be newly developed using the tailrace (in the dry season) from the Sundarijal power station and a direct intake from the Bagmati river (in the rainy season). The groundwater source comprises water abstracted from the existing wells in the Gokarna, Dhobi Khola, and Manohara well fields.

The groundwater, after pre-treatment in the bio-filter (19,100 m^3/d) for highly concentrated ammonia nitrogen removal, is to be treated with a new treatment plant in parallel with the surface water. The treated water will then be transmitted by pumps to the existing Mahankal Chaur reservoir (capacity 9,000 m^3) for supply to the southern and the eastern parts of Kathmandu city.

1) Construction of an intake facility at Sundarijal (25,400 m^3)
2) Construction of water conveyance system (Sundarijal intake to balancing reservoir to treatment plant)
3) Construction of new treatment plant at Mahankal Chaur (27,300 m^3/d)
   - Bio-filter (19,100 m^3/d)
   - Coagulant dissolution and feeding equipment
   - Alkali dissolution and feeding equipment (Sodium hydroxide and calcium hydroxide)

- Coagulo-sedimentation basin
- Rapid sand filter
- Sterilization and oxidation equipment
- Clear water reservoir
- Transmission facilities
- Electrical installations

4.3.2 Bansbari project

This project is to develop water supply facilities with a maximum water supply capacity of 22,100 m^3/d by the conjunctive use with the limited surface water in the dry season and the finite groundwater source. The groundwater will be abstracted from the existing wells in the Bansbari well field. The surface water is to be taken by expanding and improving the existing Bisnumati and Shivapuri intakes.

The groundwater, after pre-treatment in the bio-filter for ammonia nitrogen removal, is to be treated in a new treatment plant (22,800 m^3/d) in parallel with the surface water. Of the treated water, an amount of 6,800 m^3/d will be pumped to the existing Bansbari distribution reservoir for distribution to the northern part of Kathmandu city by gravity flow. The remaining 14,900 m^3/d will be transmitted to the Maharajganj reservoir by gravity flow and supplied to the central part of Kathmandu city.

1) Expansion and improvement of the existing Bisnumati and Shivapuri intakes (21,000 m^3/d)
2) Construction of water conveyance system(existing Bisnumati and Shivapuri intakes to treatment plant)
3) Construction of new treatment plant at Bansbari (22,800 m^3/d)
    - Bio-filter (17,600 m^3/d)
    - Coagulant dissolution and feeding equipment
    - Alkali dissolution and feeding equipment (Sodium hydroxide and calcium hydroxide)
    - Coagulo-sedimentation basin
    - Rapid sand filter

- Sterilization and oxidation equipment
- Clear water reservoir
- Transmission facilities
- Electrical installations

4.3.3 Implementation agency and management system

The NWSC is the implementation agency for the Project, having jurisdiction over the operation and management of water supply works under the supervision and guidance of the MHPP. The organization and number of staff members of the NWSC are shown in Fig. 4.3.1 and Table 4.3.1.

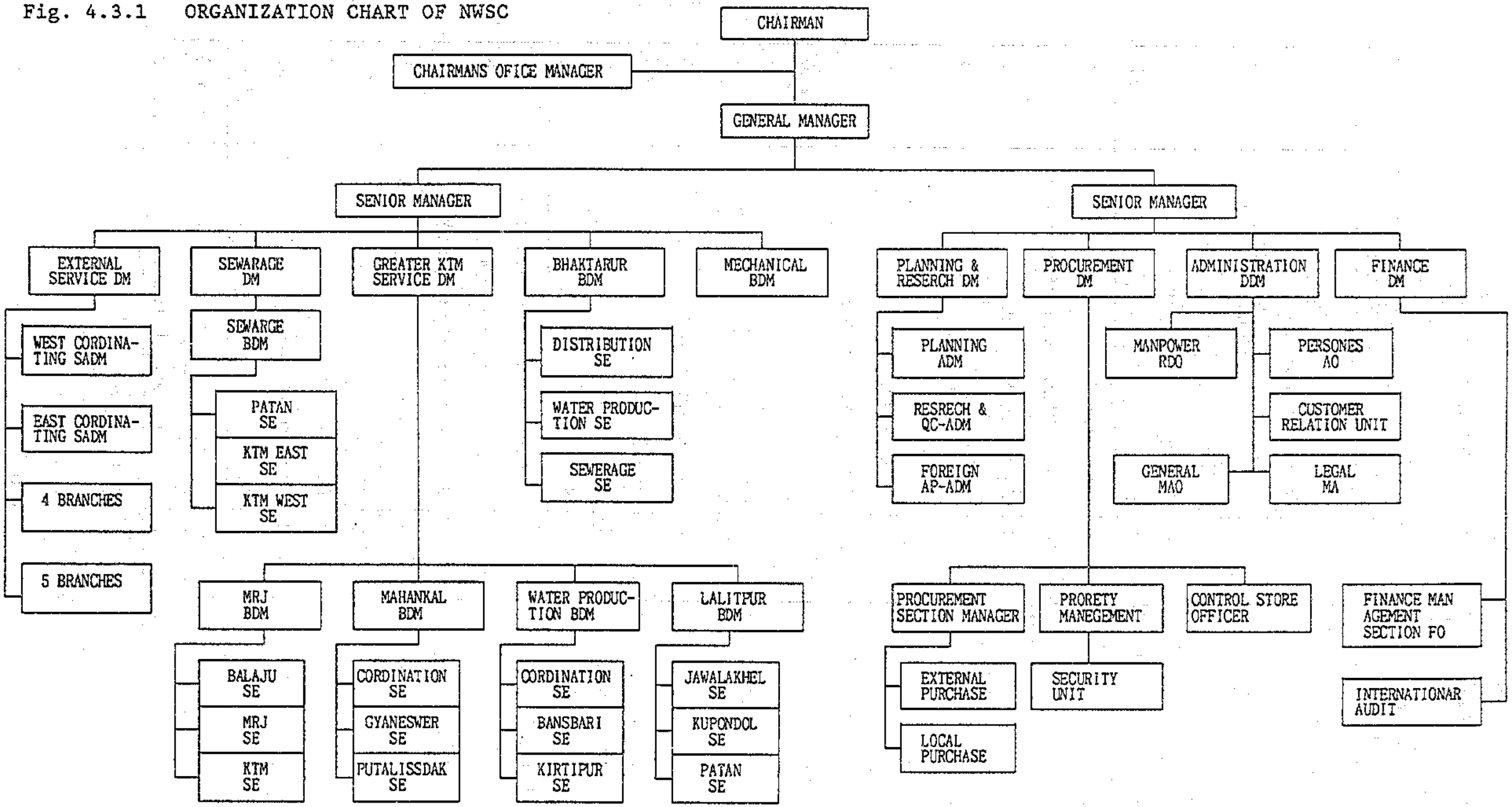
The agency directly in charge of the management of the Project is the Greater Kathmandu Service Department of the NWSC, while the subordinate organizations assign to the duties of the management of the Mahankal Chaur and Bansbari projects. The Project is to construct facilities that supplements the function of the existing water supply system adjacent to the existing facility. Its management will be undertaken by adding the required number of staff to the existing organization. The operation and maintenance organization and number of staff necessary for operation and maintenance of the Project are described in the following section, 4.3.4.

4.3.4 Operation and maintenance plan

(1) Present operation and maintenance organization

The organization of the NWSC is as shown in Fig. 4.3.1. The present organization of operation and maintenance and the management staff of the Greater Kathmandu Service Department relating to the Project is shown in Fig. 4.3.2.

Fig. 4.3.1 ORGANIZATION CHART OF NWSC



KTM: KATHMANDU
MRJ: MAHARAJGANJ

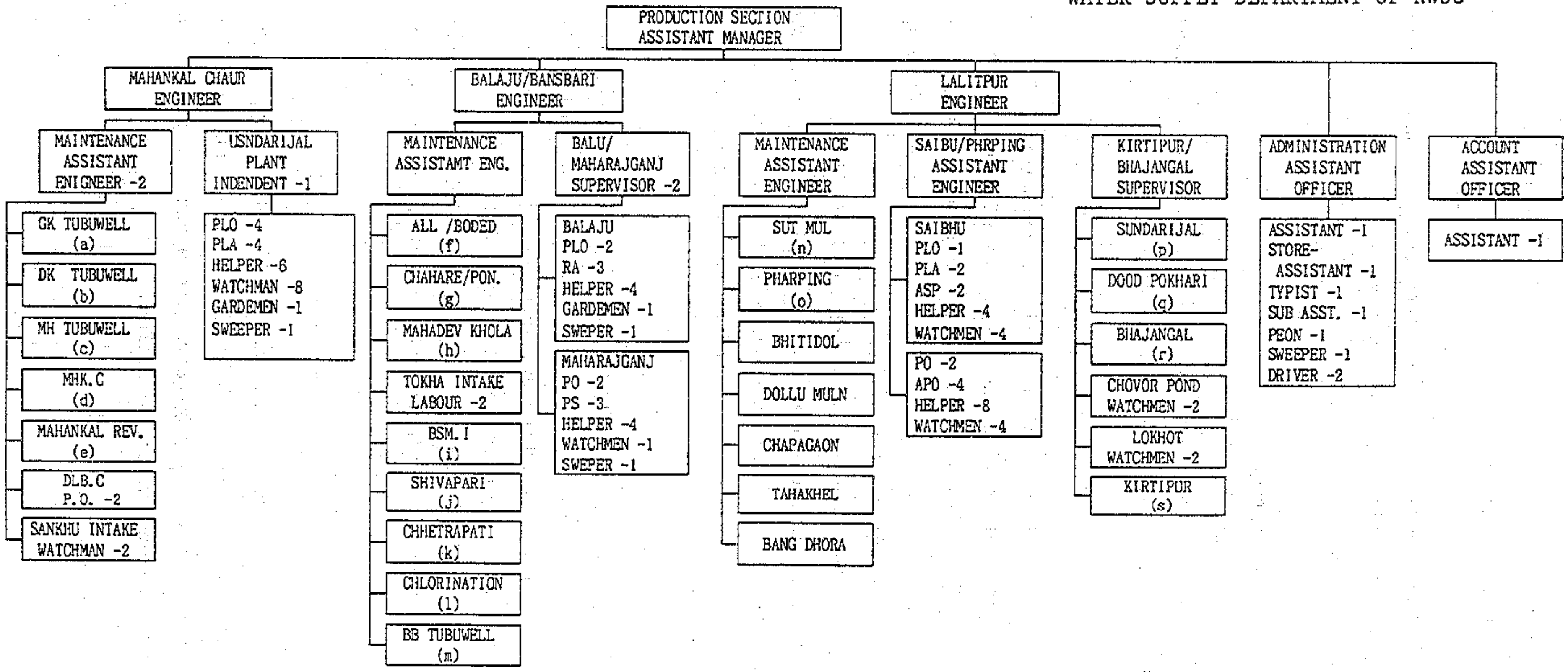
DM: DEPERTMENT MANAGER
DDM: DEPERTMENT DUPUTY MANAGER
SADM: SECTION ASSISTANT DORUTY MANAGER
ADM: ASSISTANT DUPUTY MANAGER
BDM: BRANCH DUPUTY MANAGER
SE: SECTION ENGINEER

QC: QUALITY CONTROR
AP: ASSOSIATED PROJECT
RDO: RESOURCE DIVISION OFFICER
AO: ADMINISTRATION OFFICER
MA: MANAGEMENT ADVISER
MAO: MANAGERMEN ADMINISTRATION OFFICER
FO: FINANCE OFFICER

Table 4.3.1 NUMBER OF NWSC STAFF

Central		Towns	
General Manager	1	Manager	1
Senior Manager	2	Deputy Manager	5
Manager	7	Assistant Manager	8
Deputy Manager	2	Engineer	33
Assistant Manager	4	Assistant Engineer	19
Engineer	10	Sub-total	66
Senior Chemist	2	Overseer	44
Sub-total	28	Asst. Plant Superintendent	2
Overseer	9	Chief Inspector	1
Draftsmen	3	Draftsman	3
Chemist	4	Chemist	2
Lab Technical	4	Supervisor	5
Pump Operator/Mechanic	16	Senior Mater Reader	7
Senior Mechanic	5	Plumber	210
Sub-total	41	Mechanic	30
Account Officer	2	Inspector	55
Section Officer	7	Plant Operator	20
Assistant Officer (Adm)	42	Helper	305
Junior Assistant (Adm)	69	Meter Reader	50
Sub-total	120	Sub-total	734
Driver	5	Assistant Officer (A/c)	10
Security Guard	4	Senior Assistant (A/c)	72
Helper	4	Senior Assistant (Adm)	130
Guard	6	Assistant (Adm)	425
Sweeper	9	Typist	15
Peon	30	Driver	20
Watchmen	42	Watchman/Codie	831
Coolie	3	Sub-total	1,503
Sub-total	103	Total	2,303
Total	292	Grand Total	2,592

Fig. 4.3.2 ORGANIZATION CHART OF GREATER KATHMANDU WATER SUPPLY DEPARTMENT OF NWSC



JP: JUNIOR PLUMBER
PO: PUMP OPERATOR
PLO: PLANT OPERATOR
PLA: PLANT ATENDANT
APO: ASSISTANT PUMP OPERATOR
MHK.C: MAHANKAL CHLORINATION
DLB.C: DILLIBAZON CHLORINATION
BSM.I: BISUNOMATI INTAKE

(a)JP -2
LAVOR -4
PO -2
HELPER -10
ABO -10
(b)PO -1
APO -8
HELPER -8
(c)PO -2
APO -12
HELPER -12
(d)PO -1
APO -1

(e)SUPER VISER -1
PLA -3
HELPER -3
WATCHMAN -4
LINEMAN -4
(f)SUPERVISOR -1
SENIOR PLUMBER -1
JUNIOR PLUMBER -3
LABOUR -6
LINEMAN -4
WATCHMAN -10
(g)JUNIOR PLUMBER -2
LABOUR -4
WATCHMAN -4

(h)SUPERVISOR -1
PUMP OPERATOR -1
ASSISTANT OPERATOR -2
HELPER -4
JUNIOR PLUMBER -2
LABOUR -2
(i)LINEMAN -1
WATCHMAN -2
(j)LINEMAN -1
JUNIOR PLUMBER -1
LABOUR -3
(K)ASSISTANT PUMP OPRETOR -2

(l)PUMP OPERATOR -1
ASSISTANT OPERATOR -2
HELPER -2
WATCHMAN -4
(m)PUMP OPERATOR -2
ASSISTANT OPERATOR -10
HELPER -10
(n)SENIOR PLUMBER -1
JUNIOR PLUMBER -3
LINEMAN -2
LABOUR -6
WATCHMAN -4
(o)LABOUR -2

(p)PLANT OPERATOR -1
PLANT ATTENDENT -2
ASSISTANT ATTENDENT -2
HELPER -4
(q)LINEMAN -2
WATCHMAN -2
(r)ASSISTANT PUMP OPERATOR -2
HELPER -2
WATCHMAN -2
JUNIOR PLUMBER -1
LABOUR -2
(s)JUNIOR PLUMBER -1
LABOUR -2
WATCHMAN -4

(2) Contents of the operation and maintenance

The contents of the operation and maintenance to manage the waterworks of the Project effectively are as follows:

1) Operation

a) Surface water intake operation

b) Well pumping operation

c) Treatment amount operation (operation of conjunctive treatment of surface water and groundwater)

Bio-filter

- Blower control (operation of air valves in each filter and adjustment to make the air dispersion uniform.)
- Alkali agent feeding control (adjustment to make the raw water pH 7.2 to 7.6. by adjusting the feeding amount through the feeding pump.)
- Washing (The rise of the water head of filtration is controlled, when it comes to a specified level, the raw water valve and water discharge gate are operated to backwash by the combined used of water and air.)

Coagulation control

- Feeding of coagulant (The amount of feeding through the feeding pump is increased or decreased according to changes in the quantity and quality of water and the coagulant in a proper amount is added.)
- Feeding of alkali agent (The amount of fed alkali agent is increased or decreased while checking the formation of the flocks)

Coagulo-sedimentation basin

- Control of number of basins used (According to the treated water amount changing in the wet and dry seasons, the connecting gates are opened or closed to adjust the number of the basins.)

- Flocculation (Checking the formation of the flocks, the amount of the fed chemical is adjusted)
- Sludge removal (operating the sludge removal valves at specified intervals to eliminate the settled sludge)

Rapid sand filter

- Control of number of basins used (According to the change of the treated water amount in the wet and dry seasons, the connecting gates are opened or closed to adjust the number of the basins.)
- Adding of oxidation agent for groundwater (A chlorine agent for oxidization is fed for iron removal. The amount of the fed chlorine agent is increased or decreased depending on the amount of the iron and manganese.)
- Washing (The rise of the water levels of the filtration basins is checked. When the level reached a specified one or the filtration time has passed a certain length, the filtration basins are washed by operating the raw water valve, water discharge gate, and surface washing valve. In the washing back washing as well as surface washing are employed.)
- Feeding of sterilization agent (A chlorine agent is added until residual chlorine of specified concentration is detected in the treated water)

Clear water reservoir, transmission pump

- Level control of clear water reservoir (Since the clear water reservoir has the objects of storing the water of washing to the bio-filter and rapid sand filter, adjustment is made to prevent the water from coming down below a specified level.)
- Operation of transmission pump (Automatic operation interlocking with the water level of the distribution reservoir is made.)

Coagulant, alkali agent for biological filtration, alkali agent and bleaching powder

- Dissolving (A chemical is put in a dissolution tank filled with water, and it is dissolved by agitator attain specified concentration.)
- Storage (These are dissolved according to the amounts of their consumption and stored.)

Generation of sodium hypochlorite

- Generation unit

  The items of day-to-day going-the-rounds checking are as follows:

  a. Checking any leak of liquid or water from the brine pump, dilution pump, dilution tank, collective piping units, piping, sodium hypochlorite storage tank, and feeding pumps
  b. Checking the amount of salt in the salt dissolution and storage tank
  c. Checking the amounts of the saline water and dilution water
  d. Checking the values of direct current and d.c. current voltage
  e. Checking any strange noise or smell from motors and power control panels
  f. Checking the amount of salt for regeneration of the water softener

Electrical system

- Flowmeter

d) Distribution system

- Management of water level
- Management of water distribution

2) Maintenance

The items of day-to-day checking for each facility are as follows:

a) Sundarijal balancing reservoir

b) Wells

- Measurement of water level
- Well pump (The values of current and voltage)
- Flow meter
- Water pressure gauge

c) Bio-filter

- Blower (Noise, vibration, oiling and tension of belts)
- Alkali agent feeding equipment (The values of current and voltage, discharge pressure, liquid level of constant pressure tank, leakage from piping units)
- Valves for washing (leakage, operational condition)

d) Coagulation

- Coagulant feeding equipment (The values of current and voltage, discharge pressure, liquid level of constant pressure tank, leakage from piping units)
- Alkali agent feeding equipment (The values of current and voltage, discharge pressure, leakage from piping units)

e) Coagulo-sedimentation basin

- Flocculation (Formation of the flocks, volume of sludge)
- Valves for sludge removal (Sludge removal at specified interval, leakage from valves and piping units)

f) Rapid sand filter

- Oxidation agent feeding equipment (The values of current and voltage, discharge pressure, liquid level of constant pressure tank)
- Valves for washing (leakage)
- Chlorine agent feeding equipment (The values of current and voltage, discharge pressure, leakage from piping units)

g) Clear water reservoir, transmission pump

- Transmission pump (Noise, vibration, oiling the values of current and voltage)
- Water level meter (Operational condition of indicator)

h) Coagulant, alkali agent for biological filtration, alkali agent, bleaching powder solvation and storage tanks

- Dissolution and agitation equipment (Noise, vibration, oiling, the values of current and voltage, leakage from piping units)
- Transfer pump (Noise, vibration, oiling, discharge pressure, the values of current and voltage)

i) Sodium hypochlorite generator

- Acid cleaning of electrolysis bath at suitable intervals depending on operation (with 1,500 hours as a target)
- Cleaning of grass tube in area flow meter (Saturated saline) and float as needed (once every 3 to 4 months)
- Checking of concentration of available chlorine in sodium hypochlorite as needed

j) Electrical installations

- To prevent accidents such as short circuit, excessive current, lack of isolation and the falling of a thunderbolt, replacement and repair should be done through careful daily checking.

k) Emergency generator

- Oiling, checking and supplement of water in radiator, fuel, supplement of distilled water in battery, checking operational condition at specified intervals, the values of frequency, current and voltage.

l) Water quality instruments

- pH meter (Zero adjustment from time to time, span adjustment at once every 3 months)
- Turbidity meter Zero adjustment from time to time, span adjustment and cleaning of sampling system at once every 3 months)
- Residual chlorine meter (Zero adjustment from time to time, span adjustment at once every 3 months)

m) Flow meter

- Operational condition of indicator
- Checking leakage form joints

n) Distribution facility

- Water level gauge (Operational condition of indicator)
- Distribution pump (Noise, vibration, the values of current and voltage)
- Valves (leakage from joints)

(3) Organization of operation and maintenance for the Project

For the above operation and maintenance procedures to be performed properly, it is considered necessary to set up the organization and operation and maintenance staff as shown in Fig. 4.3.3.

For effective operation of the water supply facilities it is natural to arrange such an organization properly, it is also important to place the staff in the organization appropriately. The staff should be experienced technical members in their respective fields. However, it is feared that proper operation and maintenance will be difficult due to the shortage of experienced technical personnel. Consequently, there is an urgent need to train and bring up the technical personnel engaged in the operation and maintenance.

The operation and maintenance staff consist of 111 persons for the Mahankal Chaur system and 93 persons for the Bansbari system, 204 persons in total. Since the number of the beneficiaries from the Project is 285,000, the ratio of the stuff member to the beneficiaries is 0.72 to 1,000 beneficiaries. In Japan, the ratio is of about one to 1,000 beneficiaries in water supply works of scale similar to the Project.

(4) Cost of operation and maintenance

An approximate estimation of the costs of operation and maintenance based on the above plan is as follows:

1) Operation and maintenance costs in 1995

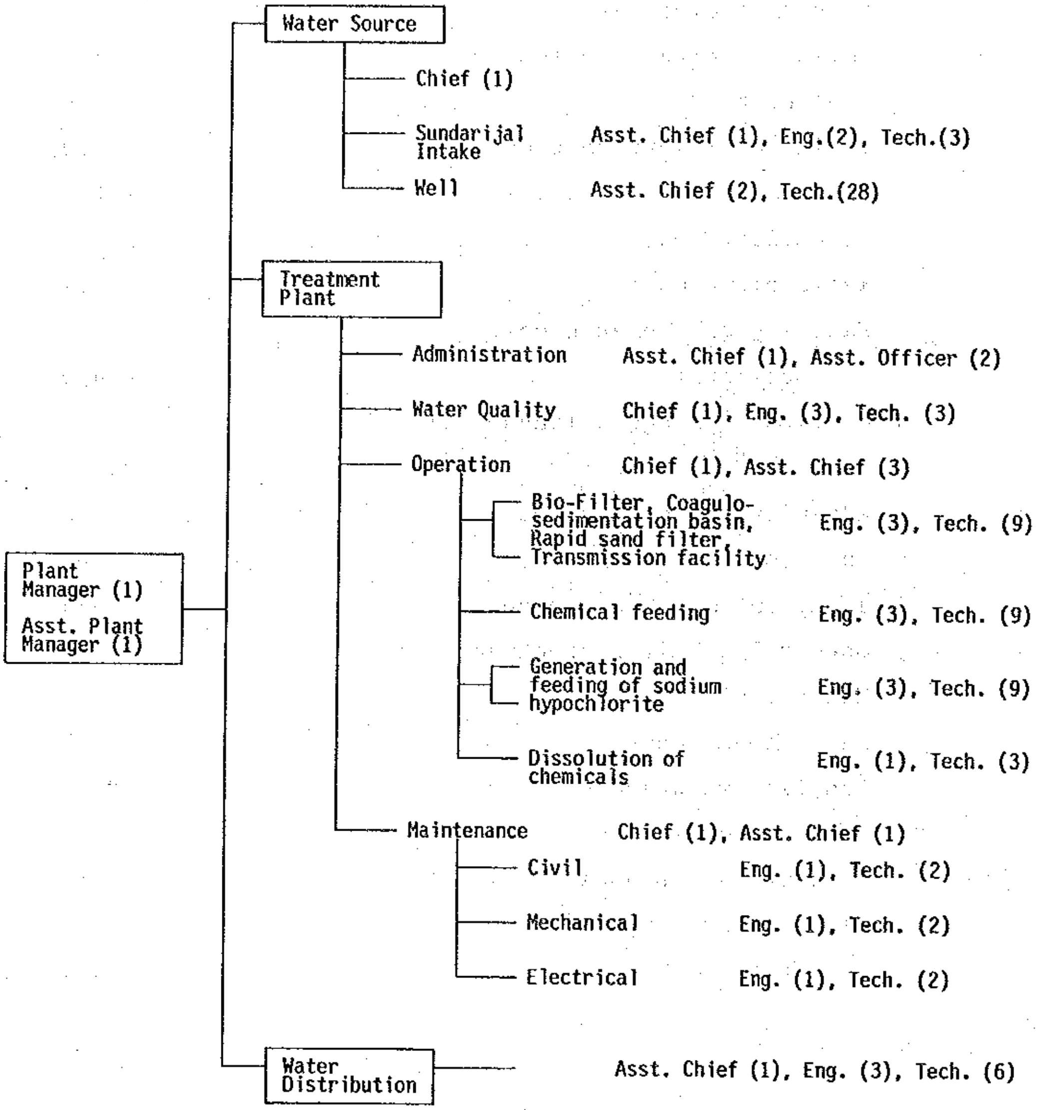
		(Thousand NRs/year)
a)	Central expenses	3,758
b)	Operational expenses (Mahankal Chaur)	
	- Personnel expenses	2,479
	- Administrative expenses	124
	- Fuel cost	36
	- Equipment maintenance cost	690
	- Chemical cost for treatment	2,386
	- Electrical cost	1,316
	- Replacement cost	653
	- Facility maintenance cost	303
	Sub-total	7,988
c)	Operational expenses (Bansbari)	
	- Personnel expenses	2,227
	- Administrative expenses	111
	- Fuel cost	60
	- Equipment maintenance cost	484
	- Chemical cost for treatment	2,098
	- Electrical cost	1,849
	- Replacement cost	537
	- Facility maintenance cost	193
	Sub-total	7,559
d)	Distribution expenses	1,689
e)	Consumer's act expenses	1,243
	Total	22,237

2) Operation and maintenance costs in 2001

(Thousand NRs/year)

a)	Central expenses	3,758
b)	Operational expenses (Mahankal Chaur)	
	- Personnel expenses	2,479
	- Administrative expenses	124
	- Fuel cost	36
	- Equipment maintenance cost	690
	- Chemical cost for treatment	2,641
	- Electrical cost	1,479
	- Replacement cost	687
	- Facility maintenance cost	303
	Sub-total	8,439
c)	Operational expenses (Bansbari)	
	- Personnel expenses	2,227
	- Administrative expenses	111
	- Fuel cost	60
	- Equipment maintenance cost	484
	- Chemical cost for treatment	2,165
	- Electrical cost	1,926
	- Replacement cost	547
	- Facility maintenance cost	193
	Sub-total	7,713
d)	Distribution expenses	1,689
e)	Consumer's act expenses	1,243
	Total	22,842

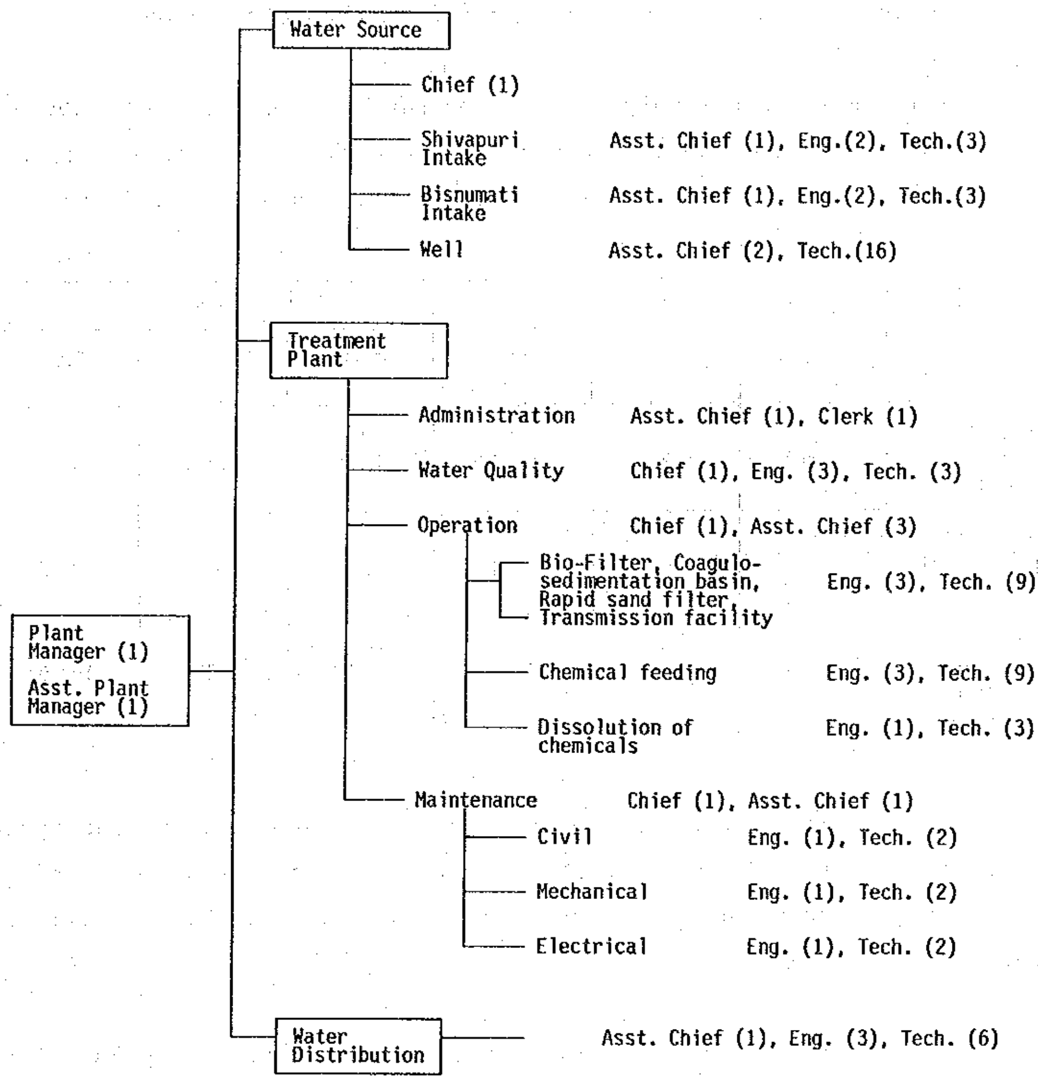
Fig 4.3.3 (1/2) OPERATION AND MAINTENANCE ORGANIZATION OF THE PROJECT (Mahankal Chaur Project)



Note: ( ) Number of staff required.

Asst. : Assistant
Eng. : Engineer
Tech. : Technician

Fig 4.3.3 (2/2) OPERATION AND MAINTENANCE ORGANIZATION OF THE PROJECT (Bansbari Project)



Note: ( ) Number of staff required.

Asst. : Assistant
Eng. : Engineer
Tech. : Technician

4.3.5 Management Plan

The operation and management of the Project is to be undertaken by the Greater Kathmandu Water Supply Department of NWSC. The operation and management is to rely mainly on revenues from the water charge.

The maximum water supply capacity of the Project will be 26,500 m^3/d for the Mahankal Chaur system and 22,100 m^3/d for the Bansbari system. The annual water supply amount of these two systems are as follow:

	1995			2001		
	Mahankal Chaur	Bansbari	Total	Mahankal Chaur	Bansbari	Total
Annual water supply amount (1,000 m^3)	7,667	6,243	13,910	8,136	6,405	13,541
Average water supply amount (Mld)	21.0	17.1	38.1	22.3	17.5	39.8
Water consumption (1,000 m^3)	5,597	4,557	10,154	6,102	4,804	10,906

According to records of the water supply amount, water consumption and revenues in 1989 (Table 4.3.2), the unit price per cubic meter of the water supply amount for house connections was 0.42 NRs/m^3 and the paid water ratio was 35%.

The factors that decide this paid water ratio are the leakage rate, conditions of water meters, arranging the good collection system, training of related personnel, enlightenment of the consumers. Taking consideration into these objects, the UWSSRP is now in progress, and it is expected that the paid water ratio will improve by a large margin in the future. Of these, the paid water ratio improvement resulting from the reduction of the leakage rate and meter rehabilitation will be about 20%, and the paid water ratio will raise to 55%.

The water rates have been left under deemed at 1.2 NRs/m^3 for a long period of time, but have raised to 2.5 NRs/m^3 in 1990 and will be further increased to 4 NRs/m^3 in the near future.

Taking this situation into account, revenues from the water charge are estimated to be as follows:

(Unit: Million NRs/year)

	1995	2001
Revenues from water charge	31,446	32,638
House connections	30,138	31,624
Standpost	1,308	1,004

On the other hand, the annual running costs will be 22.2 million NRs in 1995 and 22.8 million NRs in 2001. The annual redemption cost to be borne by the Government of Nepal will be 0.69 million NRs.

The annual expense will be 22.9 million NRs, which can be covered by the revenues from the water charge.

Regarding the annual expense of 11.3 million NRs which is related with the rise of the paid water ratio as aforementioned of the UWSSRP (requiring the improvement and rehabilitation costs of 307.8 million NRs as shown in Table 4.3.3), which is in progress with the assistance from the IDA/UNDP, the income and expenditure of the waterworks management will be balanced if the paid water ratio is raised to 60%.

Table 4.3.2 WATER SUPPLY AMOUNT, CONSUMPTION AND REVENUE IN 1989

1. Water Consumption in July 1989

	Max. water consumption (m^3/d)	Average water consumption (m^3/d)	Annual water consumption (m^3)
House connections	43,821	39,514	14,422,610
Standposts	688	620	226,300

2. Water Supply Amount in 1989

	Max. water supply amount (m^3/d)	Average water supply amount (m^3/d)	Annual water supply amount (m^3)
House connections	61,792	55,719	20,337,435
Standposts	983	886	323,390

3. Revenues

		Records of July (NRs/month)	Annual records (Million NRs)	Unit rate per water supply amount (NRs/m^3)	Unit price per effective water Quantity (NRs/m^3)
Revenues from water charge		945,325	10.23		
Breakdown	House connections	790,325	8.55	0.42	0.6
	Metered connections	660,325			
	Non-metered connections	130,000			
	Standposts	155,000	1.68	5.2	7.4

Table 4.3.3 CONSTRUCTION COST AND DEPRECIATION EXPENDITURE FOR UWSSRP

The expenses for the improvement of the wells, rehabilitation of distribution piping, improvement of water meters, leakage prevention, and putting the distribution system in good condition, in relation to the Mahankal Chaur and Bansbari systems, are set forth in the following Table:

Item	Cost (million NRs.)	Note
Improvement of wells	31.4	See Table 4.2.7
Distribution system	107.3	See Table 4.2.1 (component K4)
Meter rehabilitation and supply	12.6	See Table 4.2.1 (component K5) 32.80 x 0.385*
Leakage control	72.0	See Table 4.2.1 (component K11) 186.90 x 0.385*
Construction distribution system	84.6	JICA Water Supply Development Plan (Section 4.2.2) Bansbari 0.98 x 30.09 Sundarijal 4.58 x 30.09x0.4*
Total	307.8	

Note: * Proportion of the Project

Assuming the redemption to be the same as the above-mentioned, the annual expenses to be borne by the Mahankal Chaur and Bansbari systems will be 11.3 million NRs.

CHAPTER 5 BASIC DESIGN

CHAPTER 5 BASIC DESIGN

5.1 Design Concept

The objective of the Project is to share the important role of the long-term water supply plan as well as to solve the problems of a water supply shortage and water quality. In making the design for the Project, the above-mentioned should be thoroughly taken into consideration. Therefore, the design policy should be made such that the facilities have sufficient functions to increase the water supply amount and improve water quality, and fulfil the functions for a long time.

(1) Water sources

The water sources for the Project are the existing groundwater and the newly developed surface water sources. Taking the fact that groundwater is finite into consideration, water should be taken from the existing wells within the optimum abstraction proposed in the JICA Master Plan Study for the purpose of complementing the surface water sources in the dry season. Surface water should be taken from the expanded existing upstream water sources by gravity flow, considering irrigation water in the dry season, water pollution by agricultural chemicals and household waste water in future, electric power supply condition, and the ease of operation and maintenance.

(2) Water treatment

Since the groundwater contains much iron, manganese, and ammonia nitrogen, which reduces the effect of sterilization necessary for water supply, it should be preliminarily treated in a bio-filter and treated by coagulo-sedimentation and an iron removal process. The surface water should be treated by coagulo-sedimentation and a rapid sand filtration process that is easy to operate and maintain.

(3) Mechanical and electrical equipment, coagulant and sterilization agent

High-performance and durable Japanese mechanical and electrical equipment should be installed to maintain the efficient and long-term functions of the facilities.

The coagulant should be granular PAC made in Japan. For the sterilization agent, generated sodium hypochlorite should be used from the standpoint of safety, handling and economy, and the generating unit should be installed after being procured in Japan. However, the use will be minimized to observe the conditions of operation and maintenance, and bleaching powder lime should be used as a supplement.

(4) Construction conditions

Because skilled labor is lacking in Nepal, the structure of the facilities should be as simple as possible in order to make use of the local labor. Large quantities of brick can be easily procured locally, so that they should be used as structural material.

5.2 Design Criteria

(1) Capacity of the facilities

1) Water intake amount

Surface water:	planned water supply amount x 1.03
Groundwater:	planned water supply amount x 1.045 to 1.07

2) Water treatment amount

Bio-filter:	planned water supply amount x 1.045 to 1.07
Other treatment facilities:	planned water supply amount x 1.03

(2) Bio-filter

This is a unit process to remove an ammonia nitrogen of which is contained in groundwater, using nitrification of aerobic bacteria. Contact filter media (pumice) shall be filled into bio-treatment basin, and air blown from the bottom of the basin for the purpose of growing bacteria.

Number of basins:	10 basins
Filtration rate:	120 m/d (normal) 133 m/d (maximum)
Air blowing rate:	twice the treatment amount
Filter layer:	pumice (grain size: 8 to 12 mm, layer thickness: 1.3 m
Supporting layer:	grain size: 10 to 20 mm, layer thickness: 0.3 m
Water collecting device:	water collecting device for air washing
Effective head:	approx. 1.1 m
Backwashing:	(water) 1.0 $m^3/m^2/min$ (air) 0.8 $m^3/m^2/min$

(3) Coagulo-sedimentation basin

1) Mixing basin

In view of the very fast hydrolysis and polymerization reaction of coagulant in water, the process must be able to quickly mix coagulant and let it generate many small colloidal particles of aluminum hydroxide, diffuse them uniformly and let them reacting with turbid colloidal substances diffused in water. However, since this process might be considered as interfacial electrochemical reaction process of very complex particles, electrochemical bonding of colloidal aluminum hydroxide once formed may be destroyed by shearing strength if agitated too strongly as to impede formulation of satisfactory flocs in the ensuing flocculation process.

As indices of mixing,G value (value of the mean velocity gradient) and GT value respectively representing the amount of work or magnitude of shearing strength are available.

The target G value and GT value vary depending on the quality and treatment quantity of raw water but in general,G value of 200 to 300 sec^{-1} and GT value of 12,000 to 15,000 are aimed for.

G value:	300 to 400 sec^{-1}
GT value:	12,000 to 30,000
Detention time:	approx. 1 min

2) Flocculation basin

The coagulation is the most important process in the rapid filtration treatment system and rapid and fine flocs generated in the mixing process must be ripened into heavy, hard and uniform flocs.

In order to form satisfactory floc, it is advisable to gradually decrease the G value from G value from G = 70 - 80 sec^{-1} in the high velocity zone to G = 40 - 50 sec^{-1} in the medium velocity zone and to G = 15 - 20 sec^{-1} for the low velocity zone.

Vertical buffling type

Detention time:	30 min	
G value:	at influent end:	70 sec^{-1}
	at effluent end:	15 sec^{-1}

3) Sedimentation basin

Most of the flocs that have grown large and heavy through the steps of chemical feeding, mixing, and flocculation are now precipitated and separated by the settlement, which reduces the load on the subsequent rapid sand filtration process.

Horizontal flow type

Detention time:	(surface water)	3 hr
	(groundwater)	1 hr

Flow rate in basin:	15 to 40 cm/min
Sludge removal hopper:	It is assumed that 80% of the flocs will be settled in one third of the basin area upstream. The hopper is to be installed there to remove sludge at appropriate intervals.

(4) Rapid sand filter

This is the process of filtering fine flocs that have passed the sedimentation basin at the specified filtration rate or less, removing them by seizing them as they stick to the surface of the filter material, and obtaining the finally treated water.

Filtration rate:	(surface water) max. 150 m/d
	(groundwater) max. 300 m/d
Backwashing:	0.6 m^3/m^2/min x 6 min
Surface washing:	0.2 m^3/m^2/min x 4 min, fixed type
Filter layer:	effective diameter 0.6 mm
	uniformity coefficient 1.6 or less
	layer thickness 0.6 m
Gravel layer:	2 to 4 mm, 4 to 6 mm, 6 to 10 mm, 10 to 20 mm
	thickness of each layer 50 mm
Water collecting device:	self-washing porous blocks
Effective filtration head:	0.9 m

(5) Clear water reservoir

The clear water reservoir has the function of adjusting an moderating changes in the amount of treated and transmitted water, maintaining the treatment amount at a specified rate. The capacity of the reservoir should be enough to buffer the effects of power failures and changes in transmission amount.

Capacity: 1 hr

This also should be used as a pump pit.

(6) Coagulant feeding equipment

Coagulant: PAC (poly aluminum chloride), Al_2O_3 30%

PAC should be used after it is dissolved in a 5% Al_2O_3 solution.

Feeding ratio: $P = 8.7 + 2.2 \sqrt{T}$ (T: turbidity)

Average feeding rate: (5% solution) 20.7 mg/l, (30% PAC) 3.5 mg/l

Maximum feeding rate: (5% solution) 40.0 mg/l, (30% PAC) 6.6 mg/l

Capacity of dissolution tank:

0.4 m^3 x 2 tanks

(7) Alkali agent feeding equipment for bio-filter

In order to increase a nitro-bacteria, inject a sodium hydroxide, and then adjust into pH 7.2 to 7.6.

Alkali agent: Sodium hydroxide

Sodium hydroxide should be used after it is dissolved in a 10%, and feed.

Average feeding rate: (10% solution) 100 mg/l

Capacity of storage tank:

maximum daily feeding amount

(8) Alkali agent feeding equipment

pH and alkalinity in the surface water for the Project is generally low. Especially, it shows in the wet season. Therefore, alkali agent should be fed in order to make coagulation efficient high.

Alkali agent: lime

lime shall be used for dissolving in 20% solution.

Feeding ratio: 18 mg/l (wet season)
4 mg/l (dry season)

Capacity of storage tank:
maximum daily feeding amount

(9) Sterilization and oxidation agent feeding equipment

Here a chlorine agent is fed to oxidize manganese contents in the groundwater and to sterilize the treated water.

Groundwater
- Maximum: 3.6 mg/l (effective chlorine)
- Average: 1.8 mg/l (ditto)

Surface water (wet season)
- Maximum: 5.0 mg/l (ditto)
- Average: 2.5 mg/l (ditto)

Surface water (dry season)
- Maximum: 3.0 mg/l (ditto)
- Minimum: 1.5 mg/l (ditto)

(Generated sodium hypochlorite)
- Sterilization agent:
  1.2% generated sodium hypochlorite solution
- Sodium hypochlorite generation unit
- Water softener and salt dissolution tank

(Bleaching powder)
- Sterilization agent:
  bleaching powder (15% effective chlorine)
- Dissolution tank: 2 tanks (with dissolution agitator)
- Transfer pump
- Constant flow rate control apparatus
- Storage tank: maximum daily feeding amount

(10) Structure of water tanks

The above-mentioned treatment facilities are formed of water tank structures consisting of a number of basins. The depth of water in the tanks being three to five meters, when a tank is full of water while an adjacent one is empty as a result of the necessity for continuous water supply, big water pressure acts on the bulkhead. Also, water leakage from cracks caused by a temperature difference or differential settlement should be prevented as far as possible. The structure of the water tanks is to be made of reinforced concrete, and in making the structural design, the structure is to have high degrees of pressure resistance and water tightness. So that, presupposing adequate quality control of concrete and the supply of high-quality reinforcing bars from Japan, the design is to be made according to the Standards of Design Reinforced Concrete Structure of Japan. The allowable unit stress of the materials should be as follows:

Unit compressive stress of concrete:	$\sigma ca = 80.9\ kg/cm^2$
Unit tensile stress of reinforcing bar:	$\sigma sa = 1,800\ kg/cm^2$
Unit shearing stress of concrete:	$\tau d = 4.25\ kg/cm^2$

(11) Foundations

The inclination of a structure due to differential settlement makes the uniform overflow control of treatment facilities difficult, reducing the treatment function. Accordingly, in designing the foundation work only sufficient bearing capacity but also a foundation with uniform capacity throughout the structure are required.

The bearing capacity of the foundation ground at the places of the planned treatment plants, according to small-scale tests of bearing capacity of ground made in this latest field survey, is 4 to 8 t/m^2 at Mahankal Chaur and 6 to 15 t/m^2 at Bansbari. On the other hand, the loads of the structures are 5 to 10 t/m^2.

In the Project, since the bearing capacity of ground for all the structures of the Mahankal Chaur treatment plant is insufficient, all the structures are to have pile foundations. At the Bansbari treatment plant the shortage of the bearing capacity of the foundation ground only for the bio-filter requires a pile foundation there; the structures of the other facilities are planned to have spread foundations.

If a ground layer of 1 m to 2 m depth below the structure bottom gives enough bearing capacity, the displacement method by using good quality earth can be studied.

To decide the final foundation methods, such as the pile foundation and laced foundation, and the pile length, a detailed survey is needed in making the detail design stage.

The piles to be used in the Project are to be square-shaped reinforced concrete piles, 350 x 350 mm, which will be driven in with a diesel hammer.

5.3 Basic Plan

5.3.1 Mahankal Chaur project

(1) Outline

A treatment plant with a maximum water supply capacity of 26,500 m^3/d (including intake and conveyance facilities for the new surface water source) should be constructed at the existing Mahankal Chaur reservoir by using both the newly developed surface water source and the existing groundwater source.

The treated water is to be supplied from the existing Mahankal Chaur reservoir (capacity of 9,000 m^3) to the eastern and southern distribution areas of Kathmandu city.

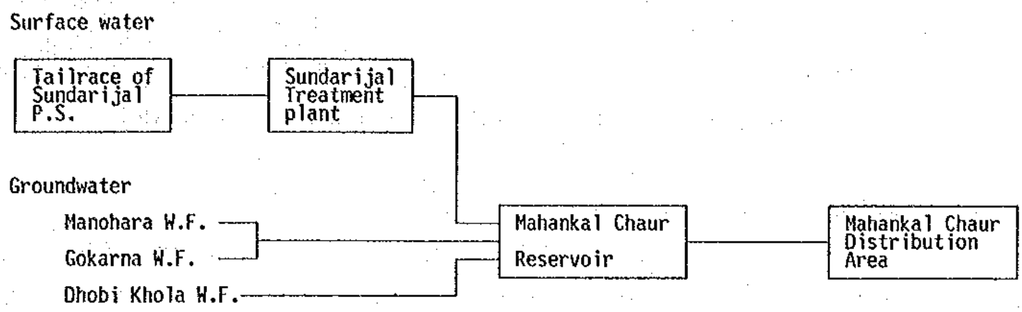
The present water supply system is such that the treated water from the Sundarijal treatment plant and groundwater from three well fields, i.e. Gokarna, Manohara, and Dhobi khola, are mixed in the Mahankal Chaur reservoir and supplied to the city of Kathmandu.

In this project, the Sundarijal treatment plant is to be separated from the Mahankal Chaur system (The distribution of the separated system will be made not through the existing Mahankal Chaur reservoir but through newly installed reservoirs in the city.) and the water supply system of this project will use water both from the above-mentioned well fields and from the newly developed surface water source.

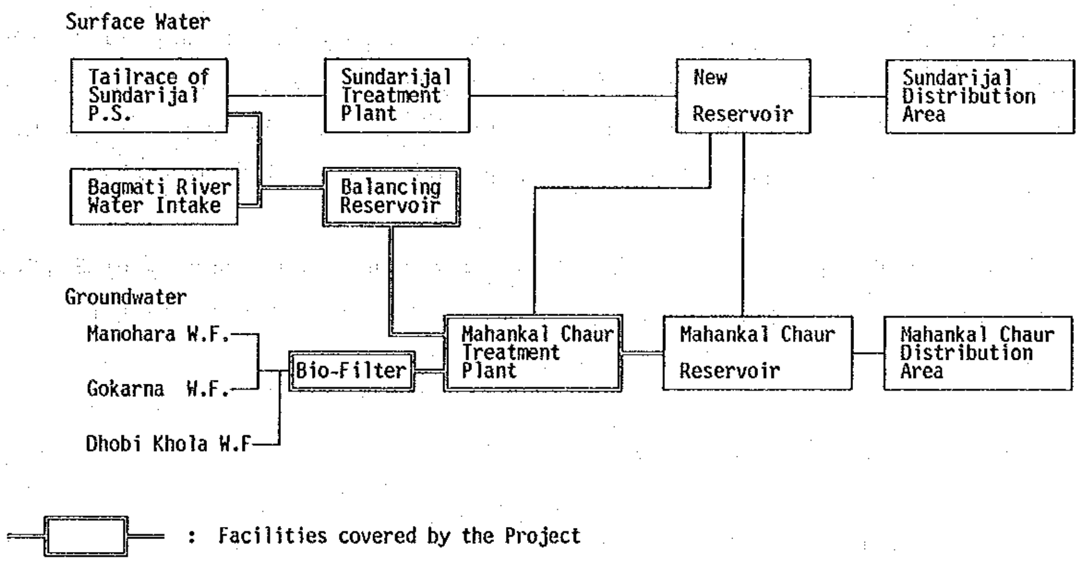
The water supply capacity of the existing system was 8,427 m^3/d in 1989, 11,620 m^3/d in 1991, and the maximum capacity will be 26,500 m^3/d after implementing this project.

A schematic drawing of the present and planned water supply systems are shown as follows:

Present System



Planned System



(2) Water intake facilities

1) Newly developed surface water sources

The planned intake amount should be taken in combination with the following three methods:

a) Of the tailrace from the Sundarijal power station, a flow rate exceeding the intake quantity of 20,600 m^3/d for the Sundarijal treatment plant should be taken.

b) Water should be taken from the penstock (ϕ450 mm) of this power plant by branching and reducing water pressure.

c) Water should be taken at a rate of 25,400 m^3/d through an intake pipe of ϕ500 mm from the Bagmati river at a point 200 m upstream of the Sundarijal treatment plant.

2) Existing groundwater sources

Water should be taken at a maximum rate of 19,100 m^3/d (annual average of 5,150 m^3/d) from the Manohara well field (5 wells), Gokarna well field (5 wells), and Dhobi Khola well field (3 wells).

Although the abstraction from the three well fields was 13,480 m^3/d in March 1991, according to the results of analysis of the operation records the inflow rate to the Mahankal Chaur reservoir is estimated to be 11,620 m^3/d because of the water supply for the living inhabitants along the course of the conveyance piping and a loss due to leakage.

Accordingly, it is desired that a maximum pumping capacity of 22,200 m^3/d should be secured by promptly executing the well improvement plan by the UWSSRP.

(3) Water conveyance facilities

1) Water conveyance facilities for groundwater source

Use of the existing piping.

2) Water conveyance facilities for surface water source

Balancing reservoir: A 4,600 m^3 reservoir should be constructed in the Sundarijal treatment plant.

The capacity of the reservoir, by adding the existing 10,000 m^3 balancing reservoir, equals 12 hours detention time for water of a quantity of 29,100 m^3/d which includes the amount from the existing Sundarijal treatment plant. However, if the improvement plan for the Sundarijal treatment plant is carried out in future, the capacity of the reservoir will become 9,600 m^3 and the detention time would become 8 hours since the existing reservoir would be reduced by 5,000 m^3.

Water conveyance piping:

Total length:	9,130 m (From the balancing reservoir to a water receiving well of the Mahankal Chaur treatment plant.)
Pipe diameter:	500 mm
Material:	VM pipe, DCIP
Air valve:	at 11 places
Drainage:	at 9 places

(4) Treatment facilities

Both groundwater and surface water should be treated in the treatment plant. The monthly treatment amount for each unit process is shown in Table 5.3.1. The treatment capacity of each unit process should meet these treatment amounts. The capacity of the bio-filter should be 19,100 m^3/d. The capacity of the coagulo-sedimentation basin and rapid sand filter should be such that the following three cases can be treated at the same time.

(Unit: m^3/d)

	Case 1 (May)	Case 2 (June)	Case 3 (September)
Groundwater	18,800	13,400	0
Surface water	8,500	12,800	25,400

Table 5.3.1 MONTHLY TREATMENT AMOUNT OF UNIT PROCESS
(Mahankal Chaur Treatment Plant)

(Unit: m^3/d)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Groundwater												
Bio-filtration	-	-	13,400	15,400	19,100	13,800	-	-	-	-	-	-
Coagulo-sedimentation	-	-	13,000	15,000	18,800	13,400	-	-	-	-	-	-
Filtration for iron removal	-	-	13,000	15,000	18,800	13,400	-	-	-	-	-	-
Surface water												
Coagulo-sedimentation	19,700	15,400	8,500	8,500	8,500	12,800	25,400	25,400	25,400	23,400	16,300	15,200
Rapid sand filtration	19,700	15,400	8,500	8,500	8,500	12,800	25,400	25,400	25,400	23,400	16,300	15,200

1) Bio-filter

a) Treatment capacity: 19,100 m^3/d

b) Number of basins: 10 basins

c) Filtration area per basin:
15.9 m^2 (2.46 m x 6.46 m)

d) Filtration rate: 120 m/d (normal)
133 m/d (maximum)

e) Filter layer: pumice (grain size: 8 to 12 mm, layer depth: 1.3 m)

f) Supporting layer: gravel (grain size: 10 to 30 mm, layer thickness: 0.3 m)

g) Water collecting device:
water collecting device for air washing

h) Raw water distribution device:
0.9 m wide rectangular weir,
ϕ300 mm soft seal valve.

i) Drain device: water discharge trough: 300 x 300 x 2,700 x 4 pieces/basin
water discharge gate: 450 mm square

j) Washing: clear water gate: 500 mm square
backwashing rate: 1.0 $m^3/m^2/min$
backwashing time: 8 min
air washing rate: 0.8 $m^3/m^2/min$
air washing time: 6 min

k) Replenishment water unit:
replenishment water pump (This should also be used for the rapid filtration basin.)

l) Blower unit: ratio of treatment amount/air blowing amount = 1/2
blower: 13.2 m^3/min x 6 mAg x 30 KW x 3 units

2) Water receiving well and mixing basin

a) Number of basins: 2 basins
b) Capacity per basin: 53 m^3 (2.5 m wide x 5.6 m deep x 3.8 m long)

c) Detention time: approx. 3 min
d) Mixing method: fall gravity type

3) Flocculation basin

The capacity is studied for the above-mentioned three cases.

	Groundwater	Surface water	Total
Case 1	$\frac{18,800}{24 \times 2} = 392$	$\frac{8,500}{24 \times 2} = 117$	569 m^3
Case 2	$\frac{13,400}{24 \times 2} = 279$	$\frac{12,800}{24 \times 2} = 269$	546 m^3
Case 3	$\frac{0}{24 \times 2} = 0$	$\frac{25,400}{24 \times 2} = 529$	529 m^3

Therefore, this shall be 48 m^3 x 12 basins.

a) Capacity per basin: 48 m^3 (1.0 m wide x 2.95 m deep x 8.1 m^3 long x 2 rows)
b) Number of basins: 12 basins
c) Detention time: 30 min
d) Type of flocculation:
vertical buffling type
(lower bent section 5, overflow weir 4)
G value: 66 to 15 sec^{-1}
total head loss: 260 mm

4) Sedimentation basin

The capacity is considered for the above-mentioned three cases.

	Groundwater	Surface water	Total
Case 1	$\frac{18,800}{24} = 748$	$\frac{8,500}{24/3} = 1,063$	1,847 m^3
Case 2	$\frac{13,400}{24} = 559$	$\frac{12,800}{24/3} = 1,600$	2,159 m^3
Case 3	$\frac{0}{24} = 0$	$\frac{25,400}{24/3} = 3,175$	3,175 m^3

a) Capacity per basin: 815 m^3 (7.0 m wide x 2.8 m deep x 41.6 m long)
number of basins: 2 basins

b) Capacity per basin: 534 m^3 (4.6 m wide x 2.8 m deep x 41.6 m long)
number of basins: 3 basins

c) Detention time: (surface water) 3 hr
(groundwater) 2 hr and 50 min

d) Flow rate: (surface water) 23 cm/min,
(groundwater) 24.4 cm/min

e) Sludge removal equipment:
discharge pit: capacity 3.86 m^3
number of pits: 60 pits
sludge discharge valve: 20 nos. (Sludge shall be discharged using one discharge valve of ϕ300 mm for three pits.)

5) Rapid sand filter and filter for iron removal

The filtration area is decided for the above-mentioned three cases.

	Groundwater	Surface water
Case 1	$\frac{18,800}{300} = 62.7\ m^2$	$\frac{8,500}{150} = 56.7\ m^2$
Case 2	$\frac{13,400}{300} = 44.7\ m^2$	$\frac{12,800}{150} = 85.4\ m^2$
Case 3	$\frac{0}{300} = 0\ m^2$	$\frac{25,400}{150} = 169.4\ m^2$

a) Filtration area per basin:
18.8 m^2

b) Number of basins: 10 basins

c) Filtration rate: maximum:
(surface water): 150 m/d
(ground water): 244 m/d
normal:
(surface water): 135 m/d
(groundwater): 195 m/d

d) Filter layer: sand (effective diameter: 0.6 mm, uniformity coefficient: less than 1.8)
layer thickness: 0.6 m

e) Supporting layer: gravel (2 to 20 mm)
layer thickness: 0.2 m

f) Water collecting device:
self washing porous blocks

g) Raw water distribution device:
0.9 m wide rectangular weir
ϕ350 mm soft seal valve

h) Drain device: water discharge trough: 300 x 300 x 2,900 x 4 pieces/basin
water discharge gate: 450 mm square

i) Backwashing: backwashing rate: 0.6 m^3/m^2/min x 8 min
backwashing flow rate: 18.8 m^2/basin x 0.6 m^3/m^2/min = 11.3 m^3/min x 8 min = 90.4 m^3
replenishment water flow rate: maximum 3.8 m^3/min
replenishment water pump: 4.0 m^3/min x 7 m x 7.5 KW x 2 units, 4.0 m^3/min x 25 m x 30 kw x 1 unit (This should also be used for the surface washing pump.)
replenishment water pipe: φ200 to φ300 mm

j) Surface washing: surface washing rate: 0.2 m^3/m^2/min x 5 min
surface washing valve: φ200 mm soft seal valve
surface washing pump: 4.0 m^3/min x 25 m x 30 KW x 2 units
fixed-type surface washing device
surface washing pipe: φ250 mm

k) Clear water equipment:
clear water gate: 450 mm square

l) Filtration control weir:
1.5 m wide rectangular weir x 10 units.

6) Clear water reservoir (This should also be used as the transmission pump pit.)

a) Number of basins: 2 basins
b) Capacity per basin: 560 m^3
c) Detention time: 1 hr
d) Inflow gate: 450 mm square x 2 units
e) Outflow gate: 450 mm square x 2 units

7) Water transmission facilities

a) Transmission pump: 6.7 m^3/min x 7 m x 11 KW x 4 units

b) Transmission pipe: φ500 mm x 70 m, φ400 mm x 20 m

8) Coagulant dissolution and feeding equipment

a) Conveyance: poly aluminum chloride (PAC)
effective Al_2O_3: 30%

PAC with 30% of effective Al_2O_3 is to be dissolved and diluted into a 5% solution and then fed. The feeding rate is to be as follows:

Feeding ratio: $P = 8.7 + 2.2 \sqrt{T}$ (T: turbidity of raw water)

b) Dissolution tank: 0.4 m^3 x 2 tanks
(with inverting type agitator)

c) Average feeding rate:
surface water (wet season)
22.2 mg/l (5% solution), 3.7 mg/l (30% PAC)
surface water (dry season)
15.6 mg/l (5% solution), 2.6 mg/l (30% PAC)
groundwater
15.6 mg/l (5% solution), 2.6 mg/l (30% PAC)

Maximum feeding rate:
40.0 mg/l (5% solution), 6.7 mg/l (30% PAC)

d) Solution storage tank:
1 m^3 x 2 tanks

e) Transfer pump: 30 l/min x 2 units

f) Constant flow rate control apparatus:
2 units (constant flow rate control valve, feeding pump, constant volume tank)

9) Alkali dissolution and feeding equipment (for biological filtration)

a) Alkali: solid sodium hydroxide
(This is to be used after the dissolution of solid sodium hydroxide into a 10% solution.)

b) Average feeding rate:
20% (For adjusting pH of treated water to around 7.2 to 7.6.)

c) Dissolution tank: 0.4 m^3 x 2 tanks
(with inverting type agitator)

d) Transfer pump: 30 l/min x 2 units

e) Solution storage tank:
2 m^3 x 2 tanks

f) Constant flow rate control apparatus:
1 unit (Constant flow rate control valve, feeding pump, constant volume tank)

10) Alkali dissolution and feeding equipment (for surface water)

a) Alkali agent: lime

b) Average feeding rate:
wet season: 16/0.8 = 20 mg/l (as $CaCO_3$)
dry season: 4/0.8 = 5 mg/l (as $CaCO_3$)
(This is to be used after dissolving lime, $Ca(OH)_2$, to make a 20% solution in terms of $CaCO_3$.)

c) Dissolution tank: 0.4 m^3 x 2 tanks
(with inverting type agitator)

d) Transfer pump: sludge pump, 30 l/min x 2 units

e) Solution storage tank:
1.3 m^3 x 2 units

f) Constant flow rate control apparatus:
1 unit (Constant flow rate control valve, feeding pump, and constant volume tank)

11) Sterilization and oxidation equipment

Generated sodium hypochlorite solution with effective chlorine of 1.2% produced by the sodium hypochlorite generating equipment should be fed.

a) Feeding point: Before the filter for iron removal and at receiving well for oxidation of groundwater.
Before the filter control weir of the rapid sand filter for sterilization.

b) Average feeding rate:
for oxidation: groundwater 1.8 mg/l
for sterilization:
surface water (wet season) 2.5 mg/l
surface water (dry season) 1.5 mg/l

c) Maximum feeding rate:
5 mg/l

12) Sodium hypochlorite generating and feeding equipment

Raw salt should be fed into a salt dissolution tank and a saturated saline water solution tank where saturated saline water about 30% is formed. Dilution water which has been softened in an automated water softener should be stored in a dilution water tank.

The 30% saline water and the dilution water should be fed to an electrolytic cell after being mixed and diluted to 3% salt concentration solution via a collective piping unit through a saline water pump and dilution water pump, respectively.

The 3% saline water will be electrolyzed in the cells when passing these and sodium hypochlorite having effective chlorine of 1.2% is generated.

The sodium hypochlorite thus generated is to be stored in a storage tank and fed into each feeding point with a sodium hypochlorite feeding pump.

a) Capacity of generation:

130 effective chlorine kg/d

b) Specifications of equipment:

Refer to Table 5.3.2.

13) Bleaching powder dissolution and feeding equipment (spare)

This is to be used after bleaching powder with effective chlorine of 15% is dissolved into a 5% solution.)

a) Dissolution tank: 0.4 m^3 x 2 units (with inverting type agitator)

b) Transfer pump: 30 l/min x 1 unit

c) Solution storage tank: 0.65 m^3 x 2 units

d) Constant flow rate control apparatus: 2 units (Constant flow rate control valve, feeding pump, constant volume tank)

14) Sludge and drainage basin

a) Number of basin: 2 basins

b) Capacity per basin: 256 m^3

c) Sludge and drainage pump: 2 m^3/min x 12 m x 11 KW x 3 units

d) Drain pipe: VU pipe, ϕ200 x 350 m

Table 5.3.2 (1/3) SPECIFICATION FOR SODIUM HYPOCHLORITE GENERATOR

Equipment Name		Items	Description
Sodium hypochlorite producing unit	Brine dissolution tank Saturated brine tank	Type	Reinforced concrete (Three coats of EPO MARINE inside)
		Dimensions	W 3,400 x L 4,100 x H 1,600
		Capacity	12.6 m^3 (including the capacity of a saturated brine tank)
		Quantity	1 unit
		Accessories	Nozzle 1 set Top cover (vinyl sheet) 1 set Level switch 1 set (four set-point type)
	Brine pump	Type	Diaphragm type positive displacement pump
		Max. discharge	70.8 l/hr
		Materials	Pump head : PVC Diaphragm seat: PTFE Ball valve : Ceramics
		Motor	0.2 KW x 200 V x 50 Hz
		Quantity	2 units (including 1 spare)
		Accessories	Safety valve 2 units (set pressure: 3.0 kgf/cm^2) Back pressure regulating valve 2 units (set pressure: 2.5 kgf/cm^2) Air chamber 2 units Pressure gauge 2 sets Brine galvanometer 2 sets (transparent PVC)
	Automatic water softener	Type	Full automatic ion exchange type
		Resin quantity	100 l
		Flow rate	6 m^3/hr
		Quantity	1 unit
	Dilution tank	Type	Rectangular
		Capacity	180 l (effective)
		Materials	PVC (outside insulation)
		Dimensions	W 490 x D 491 x H 907
		Quantity	1 unit
		Accessories	Nozzle 1 set Heater (3 KW) 1 unit Temperature detector 1 unit Ball tap 1 set

Table 5.3.2 (2/3) SPECIFICATION FOR SODIUM HYPOCHLORITE GENERATOR

Equipment Name		Items	Description
Sodium hypochlorite producing unit	Dilution pump	Type	Single suction centrifugal pump (nylon coating)
		Capacity	40 l/min x 20 m
		Materials	Casing : FC 20 plus nylon coating Impeller: SUS 304 stainless steel
		Motor	0.75 KW x 200 V x 50 Hz
		Quantity	2 units (including 1 spare)
		Accessories	Safety valve 1 unit (set pressure: 2.0 kgf/cm^2) Pressure gauge 1 unit
	Brine electrolytic sodium hypochlorite producing unit (Electrolytic cell)	Type	No-membrane brine electrolytic type
		Production rate	130 kg-Cl_2/d
		Salt used	Raw salt
		Effective concentration	1 %
		Rectifier	Thylister constant current type
		AC input	200 V x 50 Hz
		Dimensions	W 1,400 x L 1,540 x H 2,000
		Quantity	1 unit
		Major materials	Structure : SS41, SUS 304 Anode : Titanium covered with special metal (ruthenium coating) Cathode : Titanium Cooling plate: PVC Cover : SS41
		Accessories	Acid washing units : 1 unit Brine concentration: 1 set refractometer Tightening tool for: 1 set electrolytic cell
	Exhaust fan	Type	Anti-corrosion sirocco fan
		Capacity	5 Nkm^3/min x 40 mmAg
		Materials	Casing : PVC Impeller: PTFE
		Motor	0.4 KW x 400 V x 50 Hz
		Quantity	2 units (including 1 spare)
		Accessories	Manual damper (PVC) : 2 units

Table 5.3.2 (3/3) SPECIFICATION FOR SODIUM HYPOCHLORITE GENERATOR

Equipment Name		Items	Description
Sodium hypochlorite solution injection unit	Sodium hypochlorite solution storage tank	Type	Closed cylindrical vertical type
		Capacity	15 m^3
		Materials	RC made (PVC lining)
		Quantity	2 units
		Accessories	Nozzle : 1 set Manhole : 1 set Lever switch : 1 set (5 set-point type) Direct sight level gauge: 1 set Air bleeder : 1 set Ladder : 1 set
	Injection unit	Type	Diaphragm pump
		Discharge rate	30 to 80 l/hr (for groundwater) 8 to 30 l/hr (for surface water) 30 to 120 l/hr (for surface water)
		Materials	Liquid contact parts shall be chemical proof
		Motor	0.2 KW x 200 V x 50 Hz
		Quantity	2 units for each
		Accessories	Back pressure regulating valve, safety valve, air chamber : 1 set Common bed : 1 set
	Piping and valves	Type of piping, valves	Hard vinyl chloride pipe for waterworks, ball valve (PVC), and others
		Pipe dia.	1.2' to 2'
Electrical & instrumentation system	Power supply control panel	Type	Indoor closed self-supported type
		Input	AC 200 V x ϕ 30 x 50 Hz
		Output	DC 220 V x 270 A
		Rectification type	Three-phase all-wave type
		Control method	Thylister constant current type
		Dimensions	W 1,100 x D 1,100 x H 2,100
		Quantity	1 panel
	Field control panel for sodium hypochlorite injection unit	Type	Indoor self-supported type
		Dimensions	W 900 x D 500 x H 2,000
		Quantity	1 panel
		Contained instrument	Control switch, and others: 1 set

15) Electrical installations

a) Power incoming equipment

Electric power should be supplied from New Chobal substation to a lead-in pole in the treatment plant grounds from where the power is to come to a power room through buried wiring.

Lead-in power:	3 phases x 3 lines, 11 KV, 50 Hz
Electric pole:	Single arm
Aerial wiring:	3.5 km
Buried wiring:	15 m

b) Incoming/transforming system

Incoming power:	3 phases x 4 lines, 11 KV, 50 Hz
Primary voltage:	3 phases x 4 lines, 11 KV, 50 Hz
Secondary voltage:	3 phases x 4 lines, 400 V - 230 V, 50 Hz
Transformer:	600 KVA (11 KV/400 V - 200 V) x 1 unit
Type of power distribution panel:	indoor closed-type distribution panel

c) Independent power generation

Generator:	3 phases x 4 lines (400 V/230 V) diesel generator
Output:	300 KVA x 1 unit
Type of cooling:	radiator cooling
Fuel:	heavy oil or light oil
Operation:	manual operation in case of power failure

d) Trunk line system

Wiring and piping work should be carried out from the secondary side of the low voltage power distribution panel in the power room to the primary side of the power control panel and distribution panel.

e) Power control system

Wiring and piping work should be carried out from the secondary side of the power control panel to each power unit in the treatment plant in order to supply electric power, and power control panels should be installed.

Distribution voltage:
3 phases x 3 lines, 400 V

Loads: Refer to Table 5.3.3.

f) Lighting and outlets

Wiring and piping work and the installation of equipment should be carried out form the secondary side of a power distribution panel to the lighting and outlets in a building in the treatment plant in order to supply electric power, and outdoor lighting facilities for the security of the plant should be installed.

Distribution voltage:
3 phases, 4 lines, 230 V
single phase, 2 lines, 230 V

g) Instrumentation

Instruments of the plant should be installed, and wiring and piping for the instruments should be provided.

Water quality instruments

Turbidimeter:	2 sets for raw water and 1 set for treated water	
pH meter:	2 sets for raw water and 1 set for treated water	
Residual chlorine meter:		1 set
Flow meter:	for ϕ500	1 set
	for ϕ450	2 sets
	for ϕ400	1 set
	for ϕ300	1 set

Table 5.3.3 LOAD LIST OF MAHANKAL CHAUR TREATMENT PLANT

Equipment	Load Capacity (kW)	Fix (Unit)	Spare (Unit)	Non-Fix (Unit)	Total Load (kW)
Bio-Filter					
Blower	30.0	2	1	0	60.0
Rapid Sand Filter					
Surface washing pump	30.0	1	2	0	30.0
Make-up pump	7.5	2	0	0	15.0
Transmission pump	11.0	3	1	0	33.0
Aluminum Sulfate Feeding Facility					
Dissolution-mixer	2.2	2	0	0	4.4
Reception pump	0.4	1	1	0	0.4
Injection pump (for surface water)	0.2	3	2	0	0.6
Injection pump (for groundwater)	0.2	2	1	0	0.4
Alkali Agent (Lime) Feeding Facility					
Dissolution-mixer	2.2	2	0	0	4.4
Reception pump	3.7	1	1	0	3.7
Mixer	0.4	2	0	0	0.8
Injection pump	0.2	4	0	0	0.8
Alkali Agent (NaOH) Feeding Facility					
Dissolution-mixer	2.2	2	0	0	4.4
Reception pump	0.4	1	1	0	0.4
Injection pump	0.2	2	1	0	0.4
Sodium Hypochlorite Generator					
Salt water pump	0.4	1	1	1	0.8
Clear water pump	0.4	1	1	1	0.8
Electrolysis	36.5	1	0	1	36.5
Electrolysis (Spare)	24.3	0	0	0	0
Injection pump	0.4	4	0	0	1.6
Bleaching Powder Feeding Facility					
Dissolution-mixer	2.2	2	0	0	4.4
Reception pump	0.4	1	1	0	0.4
Injection pump	0.2	4	1	0	0.8
Waste water pump	11.0	2	1	0	22.0
Total					226.0